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Research Article

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An Action Research Enquiry into the potential of SolidWorks in the teaching of rotation in Junior Certificate Technical Graphics

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Abstract: Technical Graphics is one of the technology subjects taught at Junior Certificate level in post- primary schools in Ireland. The Junior Certificate examination is held at the end of the Junior Cycle in post-primary schools, which caters for students aged from 12 to 15 years. As a teacher of Technical Graphics for the past seven years, I have gained a great understanding and insight into the different topics in the subject and how they are perceived by students. I concur with the State Examinations Commission report (2008) that students lack an understanding of the rotation element of transformation geometry, one of the six topics covered on the Junior Cycle Technical Graphics course. The purpose of this study is to implement a new teaching methodology through the use of SolidWorks in an effort to improve the students' visualization, spatial awareness and understanding of transformation geometry.

I engaged in an action research study of my own practice as I investigated if SolidWorks could actually be used at Junior Certificate level to improve student understanding of transformation geometry. The action research took place over a five-week period and included three cycles of research. The research was carried out with a third-year Junior Cycle group aged between fifteen and sixteen years of age and all students in the class took part in the study. The first stage of the research examined student progress as they worked through the topic following teacher instruction on SolidWorks. The second stage of the research examined the students' progress as they used the software for themselves. I carried out an assessment task with students towards the end of the study, which showed that student learning had improved in comparison to previous years.

Keywords: Action Research; SolidWorks; Technical Graphics; Transformation Geometry; Junior Certificate.

1 Introduction

The focus of this research is to examine the effectiveness of using SolidWorks in Junior Certificate Technical Graphics to aid the teaching of rotation in transformation geometry. SolidWorks is a 3D modelling software used by engineers, architects, and product designers. There is an underlying concern with student ability to complete the rotation element of transformation geometry question each year in the Junior Certificate examination which is held at the end of the Junior Cycle in post-primary schools. The introduction of SolidWorks to Leaving Certificate students revolutionized the outdated Technical Drawing course and uptake in the subject nationally surpassed previous years. In this study, students were asked to complete a design-based project on SolidWorks and create an accurate scaled model of a random device or apparatus.

I teach in a mixed secondary school in North County Dublin that caters for all students from first to sixth year, ranging in age from twelve to eighteen years old. As a teacher, I aimed to use SolidWorks in an effort to improve student spatial awareness and visualization in transformation geometry and, more specifically, the rotation element of the topic while staying within the remit of the course syllabus and specification. While SolidWorks has been seen as a very useful visual aid, it has not been introduced to Junior Certificate Technical Graphics. My interest in this research topic was generated from my ambition for the students to succeed and always making them strive for excellence. I felt that the students were performing well in almost all areas of the Technical Graphics course but year after year students failed to excel in the rotation element

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of transformation geometry. This research is timely as the National Council for Curriculum and Assessment (NCCA) is proposing changes to the current Technical Graphics Syllabus. Under the new proposals the subject will be referred to as 'Graphics' and under the new specification students are expected to become more engaged in their own learning; "The Junior Cycle allows students to make a greater connection with learning by focusing on the quality of learning that takes place and by offering experiences that are engaging and enjoyable for them, and relevant to their lives" (NCCA, 2018, p.3).

At the initial stages of this research I reflected on my own practice and questioned why students were lacking in understanding with one element of a particular topic. I felt that the lesson had become too teacher-centered and identified the need to implement a new teaching methodology where student visualization and spatial awareness were nurtured. Though this action research study, a third year group of students, between fifteen and sixteen years of age, were given the opportunity to graphically illustrate the processes involved in completing each of the elements to a standard Junior Certificate Technical Graphics question. Guskey (2002) states that teachers should be attracted to professional development and of the belief that it will expand the knowledge and skills, contribute to their growth, and enhance their effectiveness with students. This research shows that SolidWorks can be used to teach rotation or other difficult concepts in Junior Certificate Technical Graphics and points to the need for change in the subject and how we should be striving towards greater student engagement in the content.

2 Literature review

Kaur (2012) notes that the ability of educators to integrate and include ICT into their day to day practices will greatly impact the learning experience of their students. It is envisaged that the use of SolidWorks to teach transformation geometry, one of the topics within the Technical Graphics course in the Junior Cycle, will help students decide on the correct approach to completing the expected solution in 2D format. The use of 3D modelling will hopefully contribute to student's participation and learning of the rotation processes within Transformation Geometry (Eggarxou and Psycharis, 2007).

The 'Vertex' project carried out in the UK by Bailey and Moar (2002) examined the benefits to students of modelling and making 3D artefacts using ICT and how the constructivist approach to teaching enhanced learning in an otherwise abstract topic. Students were placed at the core of the research; the project monitored their learning which arose through direct participation in different processes and activities. A considerable amount of time was spent in the set-up stages of Vertex to ensure appropriate strategies were implemented to integrate the project into the class timetable in ways which ensured students had full involvement in all aspects of the project. The activities were based around a virtual world using a software called ActiveWorlds and incorporated the making of 3D objects and designs. Students were set a task of developing a virtual world suitable for avatar characters. A sense of ownership was embedded in students through the project and students felt they had a real connection to their work. At the same time a newfound confidence was established and aptitude amongst teachers in the use of ICT was also reported. As stated by Seldin (1995), teachers like other professionals should have a hunger to update themselves, to engage in professional growth and to expand their understandings. They must be up to date with the latest pedagogical techniques, student learning theories and technological advancements. "The best teachers must keep evolving to remain the best" (Seldin, 1995, p. 3).

Lumsden (1994, p.3) found that when children do not view themselves as basically competent and able, their freedom to engage in academically challenging pursuits and capacity to tolerate and cope with failure are greatly diminished. A learner's self-efficacy (Bandura, 1997) is a learner's self-belief in completing the task at hand and is directly correlated with achievement-related efforts, performance or motivation. Students with a greater self-efficacy have a greater tendency to remain focused, self-regulated and to engage in challenging cognitive processes. It was envisaged that new teaching strategies learnt through this research could improve my teaching and thus aid student motivation in class.

3 Methodology

Watkins (1991) points out that researchers should collect and analyse data around a problem and then feed it back to establish the need for change and the direction that their intervention might bring about. The approach to action research in this enquiry is that described by Kemmis and McTaggart (1988) where the research followed a cyclical or spiral movement with the following steps: plan, act and observe and reflect. Firstly, I monitored and recorded student progress on a topic they are very familiar with - Transformation Geometry. I implemented a new teaching

methodology for a period of six weeks whereby I created 3D models on SolidWorks in an effort to enhance student visualization and understanding of the topic. Farren and Crotty (2014) supporting practitioners to research their own practice enables them to grow in self-knowledge by critically evaluating and reviewing their beliefs, values and professional practices, leading to new understandings of themselves and others in ways which they experience as transformative.

I had the student participant group for two eighty-minute class periods per week. Student were aged between fifteen and sixteen years. All students were in their third year of the Technical Graphics course. They were not recruited until ethical approval was granted. Before commencing any research, a detailed plain language statement was given to the principal of the school informing him of the details and timing of the research. Parent consent forms, as well and students assent forms, were also necessary before carrying out any research. Permission to photograph students was also sought. The student faces were omitted from the photographs. An information sheet was given to the Board of Management and approved before commencing the research. A statement of intent and information sheet was sent to parents and guardians for approval and signed before students participated in the research.

Research aims were outlined to the students and they were given the opportunity to opt out of the research at any time. Parent/guardian permission slips were given out and signed before conducting the research. The students took part in the research twice a week for two eighty-minute lessons. Students were informed that they could opt out at any time and participation was not compulsory.

I maintained a reflective journal to record my thoughts at the end of each lesson and each cycle. The reflective journal was used to critically reflect on my practice and to steer the next stage in the research. In the words of John Dewey, reflective thought is 'active, persistent and careful consideration of a belief or supposed form of knowledge in the light of the grounds which support it and the further conclusions to which it tends' (Dewey, 1933, p. 118) An assessment task and a questionnaire were used to collect data. Duffy (1987) describes this method of mixing two or more research methods as triangulation where different approaches produce and reinforce the same findings. The assessment task was used to draw comparisons between the current group and a group of similar students from the previous academic year. Student questionnaires were completed before the final assessment task to generate an understanding of their perspectives on the new strategy of using SolidWorks in Technical Graphics. Stone (1993) writes that the aim of any questionnaire is to facilitate the useful transmission of information between the respondent and the inquirer. In this case Likert scale questions were designed, which provided quantifiable data about the students' motivation, attainment and overall enjoyment at the end of the research study.

All participants completed the questionnaire to give a broad perspective of opinions. The questionnaire was used to quantify factors of the research which the assessment research could not account for, including student motivation, attainment, and overall enjoyment. The questionnaires took approximately ten minutes to complete and all questions were marked on a scale of one to ten. Results were calculated and graphed.

An end of research test was used to analyse how the new strategy of teaching Technical Graphics through the use of SolidWorks had enhanced the students' progression. Results were calculated, analysed and compared to that of the previous year. The test took approximately eighty minutes to complete and was similar to the tests of the previous year to maintain accuracy in findings. The test comprised of two past Junior Certificate questions based on the topic covered. Results from tests carried out in previous years were used to compare recent test results. Percentages suggested that the students' understanding had improved overall, especially in the rotation element of the question that proved problematic with groups of a similar ability in year's previous (Table 2 Review of Results 2016 to 2019). In this research, descriptive statistics was used to calculate the mean response to different questions during the questionnaire and test results.

4 Implementation and Analysis

I analysed my current situation and practices in teaching transformation geometry and in particular the rotation element of this topic. I observed student performance in this area before commencing any course of action. As I began to take note of student progress the same issues as I expected were highlighted. Students found it difficult to complete the rotation element of the question and some even struggled with the initial setup. As stated by Mathewson (1999) thinking with images plays a central role in scientific creativity and communication. Students struggled with the completion of the question and of course their confidence was challenged which impacted on the overall classroom climate. At this point I had identified a concern that I wanted to investigate as noted in my reflective journal.

> Reflecting on my own practice was something which I hadn't done in a long time, but it was definitely a worthwhile exercise. I did notice that some students, as expected, struggled with the setting up and completion of the rotation's element of Transformation Geometry. I already thought students found this element of the topic difficult but only now have I thought about coming up with some intervention or better way of teaching this element of the question. Bowers et al (1990) suggest that the reason some students develop these abilities further than others is to do with their ability to sketch 3D objects and using this skill as a developmental tool. Often, I would ask students "does everybody fully understand that" before moving onto a more difficult concept, however under closer inspection it was easy to see that students who are struggling don't always ask for the help they need and simply try to avoid asking a question. This reflection helped reinforce my belief that some students were finding difficulty with the topic but also that some students will happily move onto the following topic on the course without knowing and understanding all that was shown in the previous topic. (KMcL, personal communication, 4 March 2019)

Throughout this study I had not thought about the fact that students sometimes find it difficult to voice their opinions in class and although it was not the aim of the study it was an issue which concerned me. According to Brophy (1987) motivation to learn is a skill learned through general experience but stimulated most directly through modelling, communication of expectations, and direct instruction or socialisation by significant others. From time to time I would carry out a class discussion with the group and simply go through questions orally talking about each of the steps involved in finding the solution. However, when discussions took place on a one to one basis students seem less confident in participating.

I will now present the cycles of action research (Table 1) that took place over five weeks comprising of three two-week cycles. My aim at the start of the research was to try and establish if SolidWorks could become an effective visualization tool in the teaching of rotation in Junior Certificate Technical Graphics.

4.1 Planning Cycle 1

4.1.1 Questionnaire

The planning stage of cycle one of the action research involved the completion of the student questionnaires. In addition, I discussed the marking scheme for the transformation geometry question with the students and explained the marks awarded for each section of the topic, including what the breakdown in marks was for the rotation element of the topic. The completion of the questionnaires took approximately ten minutes. I then gathered the data, stored it safely until the analysis was ready to be carried out. Students were asked to place on a scale of 1 to 10 how they would rate their understanding of the rotation elements of transformation geometry before completion of SolidWorks activities.

Having analysed the results of the student questionnaires, my belief that there was an underlying difficulty with the rotation element of transformation geometry was reinforced. When students were asked to rate on a scale of 1-10 their understanding of this element of the topic, only 4/20 of the group rated their understanding higher than a 5 with some only rating their understanding to be a 1 or 2.

The response of the group when asked if they found the rotation element difficult, indicated that only 4/20 disagreed or strongly disagreed with the statement, meaning the remaining 14/20 of the class at least agreed with the statement. 2/20 of the cohort had no opinion. As expected,

Table 1: Cycles of Action Research

Cycle 1 4th – 16th March	Students complete questionnaires – this data will be used to create the next approach to the research. Students will carry out a Transformation Geometry question from the textbook and omit the completion of the rotation's element of the question. I will then show students using SolidWorks the movement or rotation of the object in 3D format through the classroom overhead projector. I will observe and monitor students' progress form this point and record how successful this intervention was.
Cycle 2 21st – 29th March	For the cycle students again completed a Transformation Geometry question omitting the rotation element to the question. At this stage the students were allowed to each take a laptop from the class set and following my instruction they each drew, modelled and manipulated the figure, emulating that what was asked in the question. Following on from this, students tried to complete the question recalling what they had just done on SolidWorks. Throughout this period of the lesson I observed, monitored, and recorded students' progress once I was happy that they were confident with the use of the software.
Cycle 3 1st – 8th April	For this final stage of the research, I carried out a quick class discussion with students on what was actually happening or being asked in the question. I then, with their suggestions and help, completed the question through the use of the projector and SolidWorks. Students later completed a test comprising of two short examination questions on their own. The results of these tests were later analysed and compared to a similar set of results from the previous year.

more than 14/20 of the group were able to say that they are regularly able to fully complete a full transformation geometry question. As the class teacher this was in line with my observation of the group. I was confident the majority of students felt comfortable with the question overall, but they lacked an understanding of the final element of the topic.

When the group of twenty students were asked if they understood the other three elements of the topic; axial symmetry, central symmetry and translation, at least 14/20 of the group agreed that they had a good understanding to these elements of the topic. Only 4/20 said they had not a good understanding with 2/20 voicing no opinion.

Students were asked if they understood how to work out the rotation angle, set up the centre of rotation and the direction from the information given in the question. Only 3/20 of the class were able to say that they had a good understanding to all three steps in this part of the question. This would also be in line with the findings of the State Examination Junior Certificate Examination report (2008) for Technical Graphics, which showed that some candidates experienced difficulty in completing the rotation, especially in finding the centre of the rotation and the centre of the rotation was sometimes guessed.

When students were asked if they found it difficult to visualize what the finished image should look like when complete, 15/20 of the group either agreed or strongly agreed that they found it difficult to imagine what the images should look like when complete, with only 4/20 suggesting that they were comfortable with this element of the topic. After analysing the results of the questionnaires, I felt that the use of SolidWorks as a visualization tool could only benefit students understanding of the topic. The students' responses supported my opinion that they had a good knowledge of the first three elements of the question but found difficulty with the final part of the topic.

4.1.2 Act and Observe Cycle 1

Transformation Geometry involves the study of movement of shapes from one position to another. Junior Certificate Technical Graphics covers four different types of transformation: translation, axial symmetry, central symmetry, and rotation. The transformation that forms the basis of this research is rotation.

The focus of this part of the study was to try out a new initiative in the teaching of transformation geometry through the use of SolidWorks. Singh (2005) describes a visual aid as a device which increases the learner's experience beyond that acquired through reading. Firstly, students were asked to begin working on the first three elements of the question: axial symmetry, central symmetry, and translation. Secondly, I explained to the students what this new software was and what its capabilities were using the projector (Image 1). Following my demonstration of SolidWorks, which lasted approximately thirty minutes, we had a five-minute discussion about the topic we were working on and how we could possibly use this new software to help us complete the problem we were working on. It was a great opportunity to foster the students' interest and get them involved in the lesson.

Having already created the image on SolidWorks, I worked though the initial three stages of the topic explaining and reinforcing student understanding of the topic. Although these were areas of the question, I knew students were comfortable with, it was good to let them see a more practical application of what they had already learnt. Kunari (2006) describes how learners prefer to



Image 1: SolidWorks software

process information in different ways; the use of visual aids in teaching will help stimulate the learner experience and understanding. Once I was satisfied that the students understood the exercise, we worked through the solution on the projector using SolidWorks. I let them continue work on their drawing. I observed students' work closely as I walked around the workshop and monitored their progress. It quickly became apparent that the students showed a better understanding of the rotation element to the question once they had seen SolidWorks. However, it did become a difficult task to refocus students and get them back to the question they were working on. The students at this point seemed more interested in actually engaging with SolidWorks and carrying out the question for themselves as I noted in my journal.

> Students were capable of working on the first three elements of the topic on their own as expected. By the time students were ready to start the rotation element of the question I had prepared a model on SolidWorks similar to the figure they were working on in the question. I went through the first three stages of the topic and students seemed to fully understand what I had just shown them. Students seemed interested and focused during this part of the lesson and they enjoyed seeing a practical application of what they had being doing in class. Next, I talked through the rotation element of the question using SolidWorks with the students. I helped scaffold students and guided them to the solution asking for their suggestions and help along the way. Once students saw what was actually happening in the question they went back to their own work and tried to complete that part of the question based on what I had just shown them. (KMcL, personal communication, 14 March 2019)

4.1.3 Reflection on Cycle 1

I reflected on the new intervention of using SolidWorks to teach transformation geometry. I met with the class twice a week for a double period on a Monday and Thursdays. After cycle one, I had four days to consider how my findings would determine my planning for cycle two of the research to commence on 18th March. It was quite clear the intervention of using SolidWorks had paid dividends and students demonstrated a greater understanding of the topic. Two key findings were presented at the end of cycle one. Firstly, as expected SolidWorks can be used as a visualization tool or teaching aid and secondly, student involvement and participation increased through the use of SolidWorks; it was very useful tool as a stimulus for a lesson. Students wanted to find out more about this software and they wanted to use it for themselves. I succeeded in showing students the movements of the figure in the rotation element of the question and student progress in the topic seemed to be much improved. One of the main points I took from the cycle was that perhaps instead of showing students the processes involved in answering the question through SolidWorks, it would be more beneficial if students could practice it for themselves. In a class of twenty students of varying abilities it can be difficult to keep all students focused all the time. The atmosphere in the classroom whilst using this new software was wonderful; students were focused, interested, full of query and questions.

At the end of my first cycle of action research I thought that using SolidWorks to teach Technical Graphics was a positive experience and an initiative which should be adapted across more topics. Educators' ability to integrate and include ICT into their day-to-day practices will greatly impact the learning experience of their students (Kaur, 2012). I cannot ignore the fact that some of the content was covered at a much slower pace than usual and if employed on a long-term basis completing Technical Graphics in the allocated 240 hours could become a problem. The group I was working with had a good understanding of the topic previously and at this stage of the year it was used more as revision tool rather than teaching a new topic. It is clear to me going into cycle two that the next natural stage of progression would be to demonstrate SolidWorks and then allow students to carry out the next question using SolidWorks for themselves. I realised that this would be time consuming as they would have to learn how to use the software for the first time. But, as this was revision time of year, I was confident we could fit it into the schedule. The questionnaire worked well in finding out the students' own thoughts and opinions. It was a good starting point for this research, and I felt I had enough direction obtained from cycle one to proceed with cycle two.

4.2 Cycle 2

Cycle two was carried out in a similar way to cycle one except students experienced a more hands on approach to the software. Cycle two took place over two weeks from March 21st to March 28th. In this cycle students again observed while I demonstrated to them how SolidWorks could be used. Later in this cycle students were given the opportunity to use the software for themselves.

4.2.1 Planning Cycle 2

My focus for cycle two was to introduce students to actually using SolidWorks for the first time. Modelling has

been described as process which includes a manageable and interactive environment which corresponds to a theoretical system or procedure (Akpan, 2001). This is usually a process which would take place at a later stage or during the initial stages on Leaving Certificate Design & Communication Graphics. As expected, this took longer than it would have done with a more senior group but creating the simple 3D figures such as the cone or the sphere first helped bridge their lack of experience or understanding with the use of the software. Once I felt students were ready, we moved onto creating models similar to that asked in the question. Students were given the opportunity to manipulate, move and transform the figure as asked in the question before moving back to the board drawing.

4.2.2 Act and Observe Cycle 2

In this part of the cycle students were given a more in-depth demonstration on how to use SolidWorks. Students were introduced to the more difficult features necessary to complete the models for the different elements of the topic which they would later be modelling. I went through the complete question with students showing them how the figure could be copied and moved for each of the four parts of the question. Students then followed my instruction and reacted the movements shown to them. Students were given the opportunity to complete the models individually as I monitored the classroom observing their progress and going over any parts of the question which they found difficult. The students seemed to grasp the new techniques very quickly and showed great enthusiasm and interest in the question. Students appeared confident in what they were doing, and most were able to complete the activity without much difficulty at all.

4.2.3 Reflection Cycle 2

Students seemed to show a much greater understanding of the steps involved in the question. Their enthusiasm excelled and this was one part of the research I found surprising. Their ability to grasp the new content also surprised me**.** A lot of the content covered would normally be covered in year one of Design & Communication Graphics, but this particular group of students exceeded my expectations. Students at times showed more interest in the software than they did in the question itself. This stage of the research went well, and I was very happy with student progress. I found that students made great progress using the software and also with their ability to manipulate the figure as asked in the question (Figure 1). As I noted in the journal, at this stage of the research I felt students had performed very well and we were in a good position to carry out the assessment task in the final cycle of this research.

> Most students made great progress with the use of SolidWorks. Their ability to create, manipulate and move the figures far exceeded my expectations. At this point in the research I began to think should there be some element of SolidWorks introduced to Junior Cycle Technical Graphics in the future? Students' interest and enthusiasm to learn was also surprising. Once some students had the main task completed on SolidWorks, they enjoyed some spare time practising some new techniques which we hadn't even covered in the demonstration. Their pace and completion rate of the sample question was better than before. A lot of students were asking questions like "what would we be making in Leaving Cert using SolidWorks?" From my observation students seemed more involved in the theory and very few found difficulty. (KMcL, personal communication, 28 March 2019)

4.3 Planning Cycle 3

Before starting cycle three I again explained to the students exactly what was going to take place in this stage of the research. I was happy with the students' progress and ability to use the software but at this stage of the research I was more concerned with actually evaluating the learning and comparing to that of previous years. Annually the rotation element of the question is an area where students consistently score poorly. This year I was hoping that this intervention would have improved this statistic. For the final stage of the research I prepared a questionnaire asking student how they felt the research went and if it was something they learnt from and enjoyed.

4.3.1 Act & Observe Cycle 3

For this stage of the research I again used SolidWorks to model the two objects (Figure 1). Students were given one last demonstration on how to complete each or different transformations before starting on the assessment task. Once I was satisfied with the students understanding of the topic, I proceeded to hand out the assessment task. Students were given one hour to complete the test allowing 10 minutes at the end to complete the end of research questionnaire. I monitored students' progress by observing their work throughout the test without intervening in any way.

4.3.2 Reflection Cycle 3

I felt this cycle of the research went well and students demonstrated a much-improved work ethic throughout. Their enthusiasm and willingness to learn were the most surprising elements I took from the research. Students performed well during the recap of the topic and the test seemed to go quite well, as shown in the results. All students completed the questionnaire, and I felt the language was appropriate to their level of understanding of the topic. I was happy with how the research progressed overall and I was looking forward to analysing the results further and comparing to results of previous years.

> Overall, I am very happy with the progress shown in today lesson. Students participated well during the recap and demonstrated a good understanding of the topic. During the assessment task students seemed engaged and worked well on the two questions. Previously I would have been a little concerned about the pace at which students completed the questions but today that pace also appeared faster. Students answered the end of research question honestly and I am looking forward to critiquing and analysing their results. At this stage of the research I am both expecting and confident that improvement will have occurred.(KMcL, personal communication, 12th April 2019)

In this section of the study I will share the results of the questionnaire and the end of term assessments. Some of the findings were interesting and most were in line with the initial aims of the study. Firstly, I will analyse the results of the questionnaires before looking at the results from tests on transformation geometry from the previous three years.

Figure 2 demonstrates the students understanding of the rotation element of the topic after completing the research, the same questionnaire was used again with students. Only 2/20 of students rated their understanding to be 4 or less with 13/20 of the cohort rating their understanding to be 6 or higher. 2/20 rated their understanding to be 9 with no students indicating that they fully understood rotation (rating of 10). There was also a dramatic increase in the overall understanding of rotation among the group. Evidentially the intervention of introducing SolidWorks as a visualization tool had worked.

- Students on average rated their understanding to be 6.85 after the research.
- Students on average rated their understanding to be 3.95 before the research

With regard to students' opinions on using SolidWorks as a visualization tool, 16/20 of the group felt that SolidWorks enabled them to visualize the route to the solution and had a positive impact on their learning. 3/20 of the group either disagreed or strongly disagreed, while one student did not provide feedback.

When asked if the use of SolidWorks in their lessons helped improve their spatial awareness, 15/20 of students either agreed or strongly agreed. 2/10 felt that it had no effect and 3/20 of the group either disagreed or strongly disagreed.

When students were asked if they felt if they were better equipped to answer the rotation element of the topic having completed the research, 14/20 of the group felt they were now better equipped with only 2/20 either disagreeing or strongly disagreeing, while 4 students did not provide any feedback for this question.

In response, when asked if they would have benefited from the teaching of all elements of the topic through the use of SolidWorks (translation, axial symmetry, central symmetry and rotation), 15/20 of the class said they would like to see other elements of the topic taught in this way.

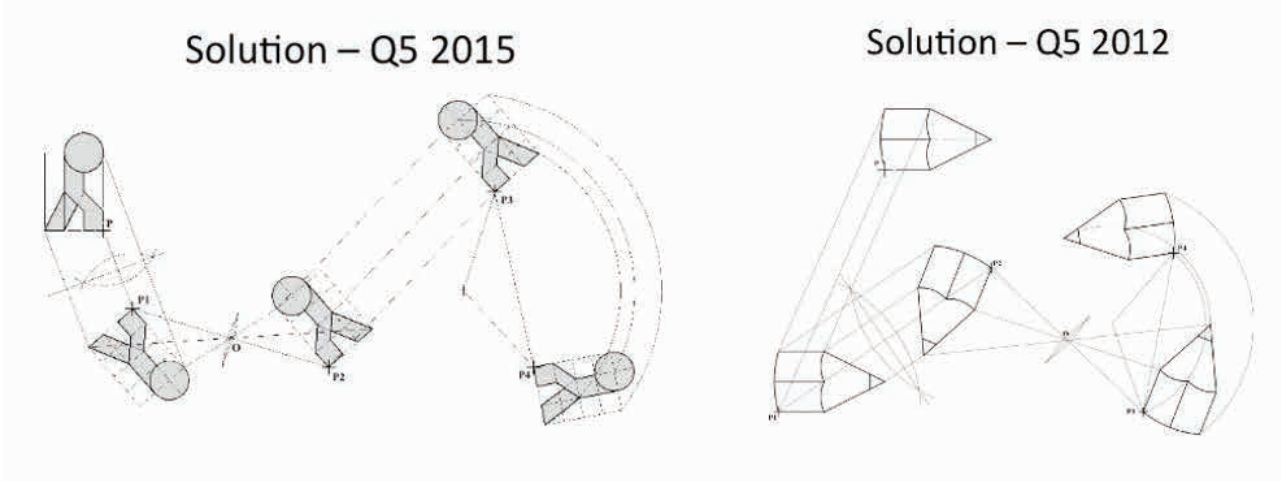
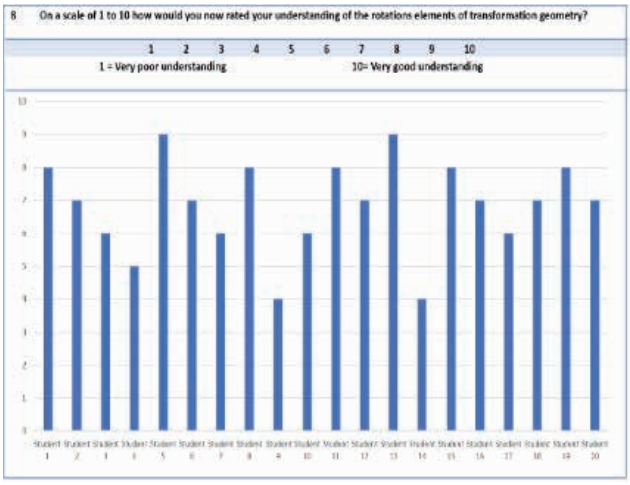


Figure 1: Pictures Explaining Translation & Axial Symmetry



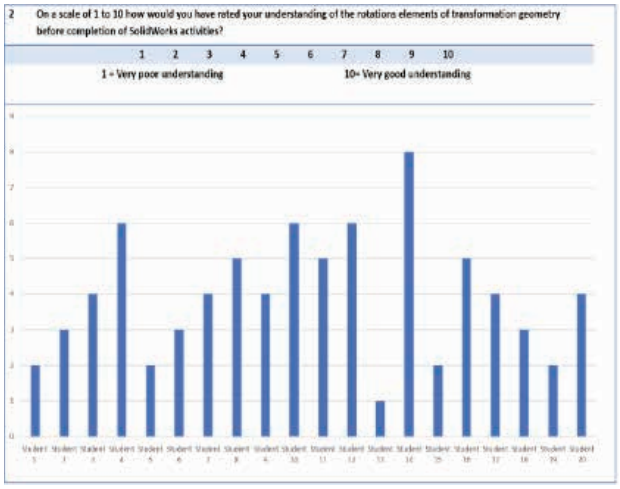


Figure 2: After Research. 12th April 2019

Before Research 7th March 2019

3/20 indicated that they would prefer the more traditional methods of teaching. 2/20 had no opinion.

When students were asked if they would like to see SolidWorks incorporated into other topics, 19/20 rated their interest in this as a 5 or higher with 13/20 of the class rating their interest to be 7 or higher. Only 1/20 of the cohort rated their interest to be less than 50%.

When asked if they enjoyed taking part in the research and would like to study Leaving Certificate Design & Communication Graphics (DCG) knowing SolidWorks would be a much greater element of the course. 13 students out of the class of 20 said they would like to study DCG with just over quarter of the group stating that they would not be considering DCG as Leaving Certificate option subject. 2 students had no opinion.

It is clear to see from the Review of Results 2016-2019 (Table 2) for the past four years that the use of SolidWorks as a visualization tool did in fact have a positive effect on the results of students. The first statistic I noticed was that for the first time in four years no students had received less than 40% in the end of term assessment. 45% of the cohort received a grade of 70% or higher and this was much higher than previous years. The next closest was in 2017 with 41% of students achieving the same result. 85% of the class achieved a grade of 55% or higher. Again, this was much higher than previous years with the closest year being 2016 with an average of 59% for the same result.

Overall, I am very happy with the results but the one statistic I noticed immediately was that the percentage of students achieving an A grade (85% or higher) showed almost no increase. With the exception of 2018 on average 10% of students have achieved this grade.

The main findings from analysing the results include;

- No student failed the test for the first time in four years.
- With the exception of the top students in the class everyone else showed great improvement.
- The intervention seemed to work better for the students who were in the D to B category. Perhaps the focus of the lesson was not challenging enough for

Table 2: Review of Results 2016 to 2019

Year / Grade	2016	2017	2018	2019
TOTAL NO. OF PUPILS	22	17	23	20
A – 85% TO 100%	2 (9%)	2 (12%)	1 (4%)	2 (10%)
B – 70% TO 84 %	2 (9%)	5 (29%)	3 (13%)	7 (35%)
C – 55% TO 69%	9 (41%)	1 (6%)	8 (35%)	8 (40%)
D – 40% TO 54%	5 (23%)	4 (24%)	8 (35%)	5 (25%)
E – 25% TO 39%	2 (9%)	3 (18%)	3 (13%)	0 (0%)
F – 10% TO 24%	2 (9%)	2 (12%)	2 (9%)	0 (0%)
AVG	54.5	53.2	51.1	65.1

the high achievers and they gained almost no further knowledge about the topic.
– The number of students achieving 85% or higher showed little improvement.

5 The Learning

One of the most important points I learnt from the research was that using SolidWorks to teach rotation in Transformation Geometry required a lot of planning and preparation. The software itself has very few limitations. However, for the purpose of this research it was about finding the most effective and efficient way to manipulate the figure asked in the question in a way in which students could easily comprehend. The success encountered during cycle one was greatly due to the time I had spent in creating the models prior to the lesson and trying out the different movements (translations) ensuring each was achievable during class. I realised the students learn best when they can visualize or see the solution for themselves. One of the most abstract things about the topic of transformation geometry is trying to picture the solution or what the completed image should look like. When students were able to see the solution for themselves, their work rate and success rate greatly improved.

At the outset of this study I made the point that difficulty with visualizing the rotation element of transformation geometry existed with Technical Graphics students of fifteen to sixteen years of age. I believe that this action research has demonstrated that point, but it has also revealed that a slight alteration to the older teaching methodologies can help overcome this problem. This research has provided me with evidence on how change in the classroom can make a positive contribute to teaching and learning.

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