Construction of A Turbine from E-Waste: A Project of the New Scientists

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Abstract
This paper reports on a joint venture between the University of Otago's Department of Applied Sciences and the College of Education which resulted in *New Scientists: Educating the next generation in science and technology* resource kits. These resource kits were designed, developed and produced in collaboration with primary schools. Their purpose is to facilitate student-led learning activities that support teachers in providing effective learning opportunities in science. The recent changes to New Zealand's curriculum, which were implemented without any professional development for in-service teachers, have further compounded primary teachers self-reporting a lack of confidence in science. *New Scientists* was developed explicitly to provide classroom teachers with a resource that supports the New Zealand's curriculum focus on the Nature of Science. Results from this project and subsequent wiki educator hits/downloads indicate that *New Scientists* provides primary schools with relevant, useful and meaningful learning opportunities.
Keywords: Primary science, Primary education, Sustainability, Integrated learning, Student-led

Introduction

Education in New Zealand has undergone some dramatic changes in the past few years with the introduction of a new curriculum document for Years 1 – 13 (Ministry of Education, 2007). The new curriculum was to be fully implemented by schools for the beginning of the 2010 school year. This resulted in a significant shift in how teachers and schools approach education, especially for science. No longer are schools selecting from a prescribed list of possible activities that students should be able to complete in a given academic year (see for example the Science curriculum document Ministry of Education, 1993). Teachers must now to take into consideration the content material that is seen as relevant, useful, and meaningful (Sexton, 2011) to their students based on their worldview.

As previously stated, this change was to be fully implemented for the beginning of the 2010 school year. It has been estimated that only about 20% of New Zealand teachers were prepared for this change (Burgon, Hipkins, & Hodgen, 2012). One of the reasons for teachers reporting a lack of readiness was the new curriculum's emphasis on the Nature of Science as the overarching strand for education through science.

This new emphasis no longer requires teachers to focus on the content strands of the living world (biology), the material world (chemistry), the physical world (physics), or planet Earth and beyond (space). Teachers now focus their students' learning, using whatever science content that is appropriate, through:

- Understanding about Science – this requires that students are able to ask questions about the science they are doing.
- Investigating in Science – means that students are expanding their world through activities, play, questions and/or simple models.
- Communication in Science - students are able to us the terminology and vocabulary appropriately as they discuss the science they are doing.
- Participating and Contributing in Science – first, students are able to relate the science they are doing to their world; and second, they are able to make decisions that impact on their world based on this science (Ministry of Education, 2007; Sexton, 2011).

With a prescribed list of activities no longer dictating the science content of their teaching programme, many teachers are now reporting a lack of content knowledge. This is compounded by the *New Zealand Curriculum's* (Ministry of Education, 2007) explicit directive to incorporate student initiated topics in their teaching. This perceived lack of content knowledge is also being reported by many student teachers as they enter their initial teacher education programme (Sexton, 2010).

As an initial teacher education lecturer and facilitator of professional development in science education, I hear far too many primary teachers and pre-service teachers saying that they do not have the background knowledge to effectively teach science. Increasing pre-service teachers' confidence in science teaching has been known to increase the amount of science that is taught in the classroom, as well as increasing appropriate pedagogical practices (Appleton & Kindt, 1999; Harlen & Holroyd, 1997). Similarly, research has highlighted the need for teachers to continue with professional development once they enter the classroom (Duschl, Schweingruber, & Shouse, 2007).

Teachers' and pre-service teachers' self-imposed content knowledge limitations in science, compounded with perceived lack of resources for science, results in many students not experiencing effective learning of science (Education Review Office, 2012). Duschl, Schweingruber and Shouse (2007) highlighted that many of the key ideas of and about science may in fact be impossible without instructional support, that is, the classroom teacher. They reiterated that for science learning to successfully engage students, it must be meaningful to them and they must be supported by the teacher.

Recently, Jadrich and Bruxvoort (2011) highlighted that scientifically literate people have "rich understanding of fundamental scientific ideas and the practices associated with doing science" (p. 3). They clarified this by saying that this does not mean they have to do science as a scientist anymore than musically literate people have to be composers or musicians. This is what I try to get across to teachers; you are not trying to be scientist or somehow turn your students into scientist. You are providing effective learning opportunities in the area of science. To do this, many have to unlearn what and how they were taught science, or even how they are currently teaching science, so that they are able to provide relevant, useful and meaningful learning experiences for their students.

What counts as quality and effective science in schools in New Zealand, has been highlighted in the recent Education Review Office's (ERO) (2012) report. ERO highlighted the characteristics that were evident in the classrooms in which effective education through science was taking place. As these schools have demonstrated, their students' evidence characteristics of students' engagement, specifically: they like doing science; are motivated by their classroom science activities; think they are learning well in science; and are enthusiastic about doing more science (see Education Review Office, 2012). Similarly, their teachers model some of the teacher characteristics ERO identified as good practice indicators, in particular:

1. High quality planning, including strategies for identifying and responding to students' prior knowledge, and for teaching them the significant scientific concepts (or big ideas).
2. Flexible approaches that take advantage of students' curiosity and are able to meet their diverse needs.
3. An emphasis on the quality of students' thinking, or conceptual development.
4. High quality investigations, reflection and discussions that help students develop their understanding of scientific knowledge and processes.
5. Engaging practical activities that allowed students to investigate their own ideas as well as those of others – these activities were collaborative, relevant, and drew on local context as well as interests of students (see Education Review Office, 2010).

This paper reports on how the University of Otago's College of Education and the Department of Applied Science worked together with two local schools to produce a resource kit (see Appendix A) that supports teachers and students in achieving relevant, useful and meaningful science. Through *New Scientists: Educating the next generation in science and technology*, primary teachers and their students assisted in the design, development, testing, and production of a resource kit that can be taken up and used in any school.

The Project

This project was initiated by the University of Otago's Department of Applied Sciences for its third-year students as their final year research design project. The project required the Design students to communicate the principles of design, technology, and maths to students between the ages of five and 12 (primary-aged students in New Zealand). In addition, their design brief required that the final product could be taken up by any teacher in New Zealand with no further instructional or expert support needed. In order to meet these goals, the Department of Applied Sciences asked the College of Education to join and help supervise this project.

At the beginning of 2011, 69 design students began to investigate a number of potential ideas that they believed could be of interest to primary-aged students. It was at this point that as a College of Education staff member I became involved in the project. The Design students were given a crash course in the 2007 *New Zealand Curriculum* (Ministry of Education, 2007) and how schools should be implementing this document in their teaching programmes. Specifically, these students were guided in their initial planning on how to focus their learning activities on the four elements of the Nature of Science: Understanding about Science; Investigating in Science; Communicating in Science; and Participating and Contributing in Science. Warrington School was approached to be included in this design project as it has a history of student-led learning with its students currently operating their own radio station and running an e-waste recovery programme for computers (see http://wikieducator.org/Warrington_School) among their other enviro-initiatives. After several discussions and planning sessions in March and April, seven Design students decided to focus their project on a resource kit (see Appendix A) which would build on and compliment Warrington's e-waste recovery programme.

In May, these seven Design students and their Design Studies facilitator were taken to Warrington school and introduced to the classroom teacher and students who would be involved in this project. The Design students were taken through the process by the Warrington students on how they strip an old computer down and then re-build it with open source software. This gave the Design students an opportunity to experience first-hand the depth of content knowledge and technical ability that these primary students possess. The Design students were able to experience for themselves the types of activities these students are currently engaging in to bring science into both their classroom and their world; that is how these students are Investigating in Science and Participating and Contributing in Science. The Design students also gained a better understanding of the depth of understanding these students already posses and the degree of confidence they have in expressing themselves by Communicating in Science. It was during these sessions that the Design students explored the design details of their project with the Warrington students to gather their interests and questions.

It was through these collaborative sessions that both the Design and Warrington students developed their Understanding about the Science. The Design students refined their project based on the input and questions from the Warrington students. Similarly, the Warrington students were able to develop and even deeper understanding of the goals and purpose behind the kit. In these May and June collaborative sessions, the project components were trialled and then finally refined down to the PH1.1 teaching kit – the construction of a turbine from E-Waste (see Appendix A). The kit includes mind maps and kit construction information for the students. There is also a lexicon of terms and web links are provided to support the teacher's delivery of this kit and students' extension beyond this resource.

After the completion of the initial resource kit at Warrington School in August it was then trialled at St Leonards School in September. St Leonards is similar to Warrington School in that it's a small semi-rural school that focuses its learning around student-led topics. It was through this second in-school testing that final adjustments and modifications were made to the PH1.1 kit throughout September and October. This kit is now available to use by any school and has been made available to schools around New Zealand via wiki educator (see http://wikieducator.org/User:Design_is_Applied_Science).

At the beginning of 2012, the students at Warrington School wanted to continue working with this project and develop additional resources similar to the construction of a turbine. Warrington School has decided to become energy self-sufficient by using only its own local resources. As a result, the Warrington students and their teachers, working with the Department of Applied Sciences, developed a water wheel that compliments the turbine.

Supporting Teacher Content Knowledge

In April 2011, Sir Peter Gluckman delivered a report from the Office of the Prime Minister's Science Advisor (Gluckman, 2011), in which he highlighted the challenges and opportunities for science education for New Zealand. He recognised the changing nature of science and the role it plays in society. More importantly, he stated that "a forward looking science education system is fundamental to our future success in an increasingly knowledge based world" (p. vi). *New Scientists* is how one university in New Zealand is seeking to meet the challenges and realise the opportunities for education through science.

The 5E approach (Skamp, 2004) has been shown to be successful in teaching scientific content to primary-aged students. The 5Es are: engage, explore, explain, elaborate, and evaluate. This approach is very useful for teachers struggling with their own pedagogical content knowledge. Specifically for this paper, the 5E approach compliments the *New Zealand Curriculum's* (Ministry of Education, 2007) overarching strand of the Nature of Science for education in science. It should be noted that many teachers are getting caught up in using learning theories and approaches that try to be as student-centered as possible, forgetting that they also play a vital role in education. Teachers need to be reminded that no one learning theory or approach is perfect. Sometimes Direct Acts of Teaching: Directing, Telling, Explaining, Prompting, Modeling, Giving Feedback and Questioning (Ministry of Education, 2006) while being very teacher-centered, are necessary. Once students have the information or material that is needed to engage them, it is then appropriate to switch from teacher-centered to student-centered learning approaches. Not every lesson should follow the same routine; both students and teachers need some variety.

The first E is to engage the students. This first E aligns well with Investigating in Science as it combines an activity the students do with the chance to ask any questions necessary to overcome any initial hesitancy. The resource kit suggests giving the students the hard drive to hold and manipulate. When you bring more than one sense into the learning, you are more than likely going to have the students engaged. That is the purpose behind the "Introduction" lesson to the construction of a turbine. Students are doing the activity while they are exposed to the learning. At Warrington School, the students had no difficultly in taking apart a hard drive from an old computer. This was not the case at St Leonards, but the "Introduction" page to the lesson plans provides the step-by-step directions, both visual and textual, needed for most teachers to ensure their students are able to complete this task. This task was completed by students in Year 4 and above (students eight to 12 years old). The younger students became frustrated and confused and lost interest. As a result, to provide an activity based project the younger students could and would participate in, the Water Wheel kit was developed in 2012 (see Appendix B).

The three activity plans: Magnetism, Electricity, and Bearings provide the opportunities for teachers to facilitate student exploration of the concepts and materials that will be needed for the final construction of the turbine. The explore step is important as this is where the students get the chance to try things out and experience what happens. This explore step mirrors the relationship between Understanding about the Science and Investigating in Science. By undertaking these activities, students explore what different components are able to do. This in turn raises further questions students will need to explore as they seek to discover the answers. This is the intent behind Understanding about the Science and Investigating in Science. The questions generated about how, why, what if and what about as they seek deeper understanding about the science lead to further and more meaningful investigations in the science. This is the step that is more likely to challenge what the students know. Students do need to experience the "WOW" factor of science, but without the corresponding "Why this happens" discussion; these experiences are more likely only going to be seen as fun by students as there is no real learning involved.

Students need to be explicitly asked to explain their explorations. This is a deliberate step to discuss what they did and why, and what were the results of what they tried. Positive learning effects have been seen in students who use discussions as a key part of the science process (Duschl & Hamilton, 2011). The students are given the opportunity to talk about the science. This deliberate Communicating in Science allows the teacher to actually hear what students are thinking and how they are making sense of the science. This facilitates the transition into the explain step of the 5Es.

The explain step allows the classroom teacher to ensure that the terminology and science content is effectively and age appropriately understood. Depending on the intent of these activities this could be: appropriate usage of vocabulary; which materials are better; what some of the differences in materials are. The elaborate step is most likely going to naturally follow any explanations that confuse or challenge what students thought they knew. This is the point most teachers raise personal concerns over their own content knowledge. Teachers need to be reminded that they do not have to know it all, but they do have to model to students what to do when you do not know the answer. Many teachers need to learn how to say "I don't know but let's find out." The lesson plans help support this by providing online resources that are easily accessible, so teachers are able to find the answers to questions that they do not understand or want further explanations around.

For the *New Scientists* resource kit, the final lesson plan is the actual construction of the working turbine. This activity is designed so that the students are able to reach a natural conclusion to the activities by producing their own working turbine. This may seem to be the natural conclusion to the exploration, explain and elaborate steps but it is not the final step in the 5Es.

The final E is evaluate. This is where the students need to be able to discuss what they did, how they did it and why this science is relevant, useful, and meaningful to them. Specifically, what did they do that challenged what they thought they knew? How did this impact on their understanding? as well as, What did they do that was like a scientist? This is where the teacher gets to hear all the summative assessment that is needed for these activities: What went well?; What stills need to be worked on?; and Where to next? This is all based on what the students have been discussing. Here is where the teacher gets to listen to them discuss all the science that they did and what they were able to accomplish. The final E of evaluate provides the students the opportunity to express not only what they are Understanding about the Science but also how it relates to their world and what they are able to do with the science, that is Participating and Contributing in Science.

Conclusions

Duschl, Schweingruber and Shouse (2007) highlighted the need for in-service teachers to continue in their own professional development. This is often easier said than done. Teachers have enormous demands placed on them for the day-to-day running of their class. I would argue that most teachers do in fact want to provide challenging and engaging learning opportunities for their students; it is just that in some subject content areas this is not that easy. Teachers, like their students, come to class with their own personal baggage and a self-perceived lack of science content knowledge is one of those obstacles (Simon, 2000). Simon (2000) concluded that teachers need to be both enthusiastic and knowledgeable about their subjects so that they provide, "well-ordered and stimulating science lessons" (p. 115).

But there is more to designing a teaching and learning opportunity than just addressing each learning demand in turn as students need to be first guided and then taught how to independently draw upon and link together the big ideas (Leach & Scott, 2000). Linn and Eylon (2006) further elaborated on this issue, claiming that students tended to localize their learning in the specific context in which it is occurring when they need to integrate all the ideas. The *New Scientists* resource kits were developed to facilitate this integration of science with social, cultural, educational, and personal experiences (Linn & Eylon, 2006). As stated, the students of Warrington School drove the second iteration of this resource kit with the intention of developing a working water wheel.

New Scientists can be located by typing "Teaching of Science" in the wiki educator search box. You are able to download all files including images of the finished kits. Since the first set of files was uploaded in 2011, the views have been constant at around 100 hits per month.

References

Appleton, K., & Kindt, I. (1999). *How do beginning elementary teachers cope with science: Development of pedagogical content knowledge in science*. ERIC document (ED448998). Retrieved from http://www.eric.gov/contentdelivery/servlet/ERICServlet?accno=ED448998

Burgon, J., Hipkins, R., & Hodgen, E. (2012). *The primary school curriculum: Assimilation, adaption or transformation. NZC at primary and intermediate level: Findings from the NZCER national survey of primary schools 2010.* Wellington, New Zealand: New Zealand Council for Educational Research. Retrieved from http://www.nzcer.org.nz/system/files/Primary_school_curriculum_Web.pdf.

Duschl, R., & Hamilton, R. (2011). Learning science. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 78-107). New York, NY: Routledge.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science to grades K-8*. Washington, D.C.: The National Academies Press.

Education Review Office. (2010). *Science in years 5 to 8: Capable and competent teaching*. Wellington, New Zealand: Educatin Review Office.

Education Review Office. (2012). *Science in the New Zealand Curriculum: Years 5 to* 8. Wellington, New Zealand: Education Review Office.

Gluckman, P. (2011). *Looking ahead: Science education for the twenty-first century*. Auckland, New Zealand: Office of the Prime Minister's Science Advisory Committee.

Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International Journal of Science Education, 19*(1), 93-105. doi: 10.1080/0950069970190107

Jadrich, J., & Bruxvoort, C. (2011). *Learning & teaching scientific inquiry: Research and applications*. Arlington, VA: National Science Teachers Association Press.

Leach, J., & Scott, P. (2000). Chilren's thinking, learning, teaching and constructivism. In M. Monk & J. Osborne (Eds.), *Good practice in science teaching: What research has to say* (pp. 41-56). Buckingham, UK: Open University Press.

Linn, M. C., & Eylon, B.-S. (2006). Science education: Integrating views of learning and instruction. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 511-544). Mahwah, NJ: Lawrence Erlbaum Associates.

Ministry of Education. (1993). *Science in the New Zealand curriculum*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2006). *Effective literacy practice in Years 5 to 8*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2007). *The New Zealand Curriculum*. Wellington, New Zealand: Learning Media.

Sexton, S. S. (2010). Science education a vehicle for the key competencies in praxis. *New Zealand Science Teacher, 125*, 38-40.

Sexton, S. S. (2011). Revelations in the revolution of relevance: Learning in a meaningful context. *The International Journal of Science in Society, 2*(1), 29-40.

Simon, S. (2000). Students' attitudes towards science. In M. Monk & J. Osborne (Eds.), *Good practice in science teaching: What research has to say* (pp. 104-119). Buckingham, UK: Open University Press.

Skamp, K. (Ed.). (2004). *Teaching primary science constructively* (2nd ed.). Southbank, Victoria, Australia: Thomson.

Appendix A


NEW SCIENTISTS
EDUCATING THE NEXT GENERATION IN SCIENCE AND TECHNOLOGY
Joshua Ureli
Sian Foster
Guy Hopley
Troy Croudis
Brian Smith
Eleanor parker
Jake Izuchi


NEW SCIENTISTS

NEW SCIENTISTS
EDUCATING THE NEXT GENERATION IN SCIENCE AND TECHNOLOGY

Introduction

Ph[1.1] Physical World Activities

Project Vision

Vision
The vision of this project is to re-imagine science education in primary schools through activity based learning.

Activity Based Learning
This resource will address the four main modules of primary level science. This project only includes a completed version of the Physical World module. The completed module will be a template for the development of the other three modules.

Learning from Junk
The main principle of this project is to reuse existing materials and components that are easily accessible. The focus for this project was what can be made from the components that make up a standard computer hard drive and how they can be used to educate primary level students.

Health and Safety

Dismantling a Hard Drive

Tools required:
Torx Screwdriver, sizes 8, 9, and 10
Phillips Screwdriver

Before dismantling ensure that the power has been disconnected from the computer for at least one day.

At the back of the computer unscrew these two screws. Be wary of small pieces.

Carefully remove the computers protective casing.

Remove the CD drive from the case by disconnecting the data and power cables at the back by pulling it out.

Remove the metal cover that is obscuring the hard drive. Be careful of sharp edges.

Remove the hard drive from the case by disconnecting the data and power cables from the back and lifting it out.

At this point, both the CD drive and the hard drive should have been removed from the computer case.

Warning. Somewhere on the motherboard should be a battery which contains toxic chemicals.

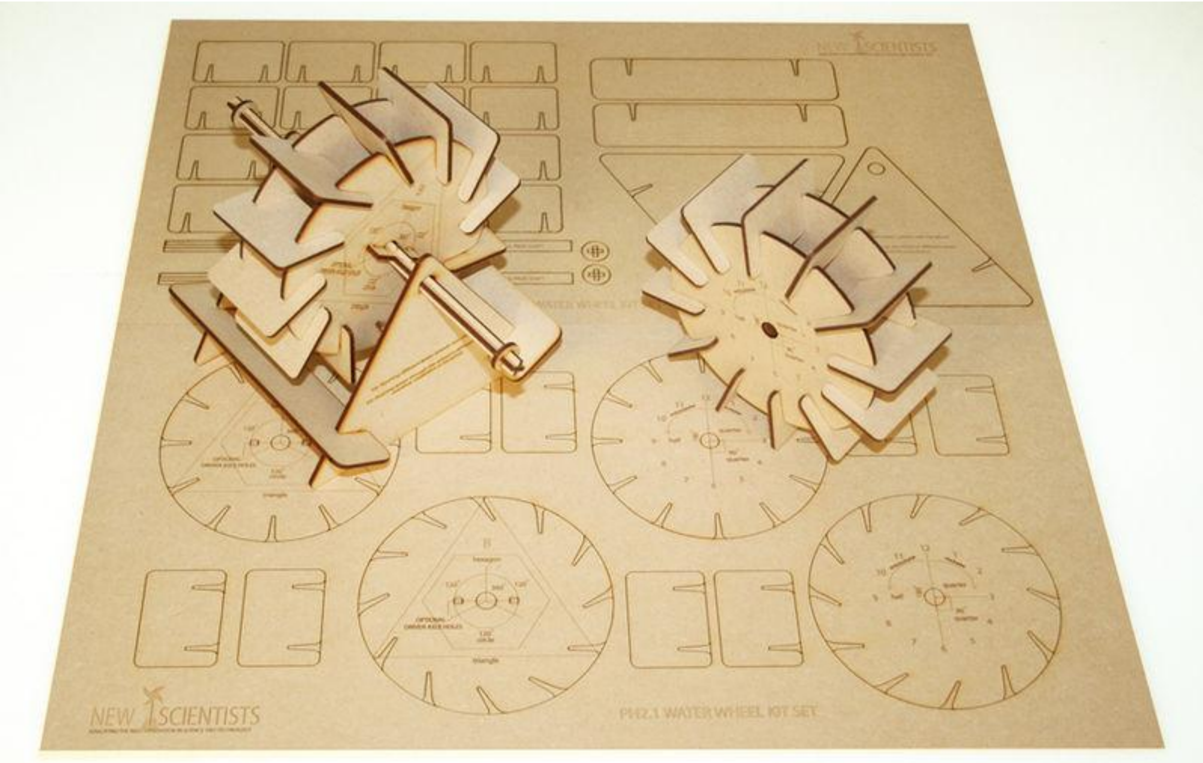
Remove the screws from the back of the hard drive to open it up.

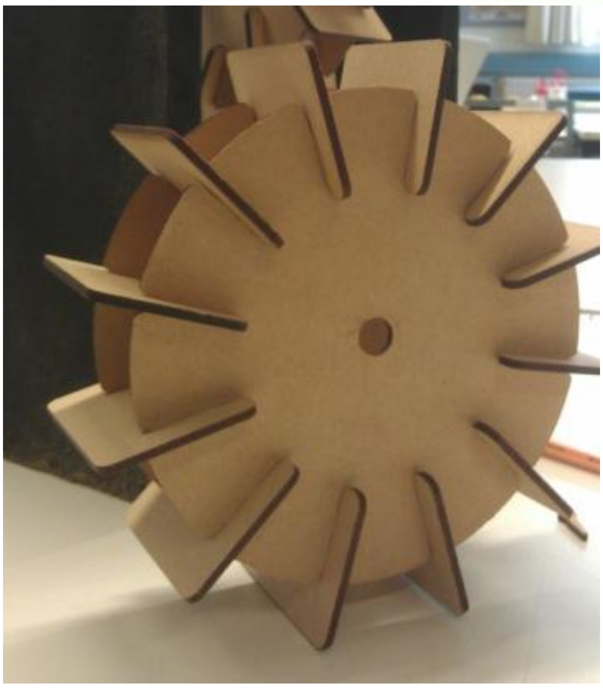
Carefully pry away the top magnet. Be careful, it will destroy electronics.

Remove the screws on the top of the bearing, take off the disks and remove the bearing.

Remove the circuit board and the screw indicated to access the second magnet.

Appendix B





Water energy plan

WORD	DEFINE	EXPLAIN
Physical:		
Axle	The shaft a wheel rotates around or on.	Fixed axles can be used to transfer energy from water to other energy.
Centripetal force	The force which keeps an object moving around a curve.	In this water wheel the centripetal force is provided by *friction* between paddles and the wheel which stops them being flung off!
Dam	Structure that holds back water; river, sea etc.	*Gravitational potential energy* exists in water behind dam.
Friction	The resistance that surfaces have when in contact with each other.	When surfaces move against each other they are slowed down, which creates heat. For example rubbing your hands together makes them warm!
Inertia	The property of mass which causes it to resist changes to its location or velocity.	It takes force to make an object move or change direction. It's easier to throw a tennis ball than a shot-put because the shot-put has more inertia.
Momentum	The combination of velocity and weight of an object.	A heavy thing is harder to stop than a light one. It has more momentum/*kinetic energy*.
Rate	The speed at which something happens.	When the wheel spins faster it is spinning at a faster rate.
Turbine	Spins, converting kinetic energy in water or air to electricity or mechanical work.	A turbine is more *efficient* than a water wheel at changing *kinetic energy* to electricity and other forms of energy.
Volume	The space taken up by an object.	Volume is not related to mass but just how much large it is.
Energy:		
Energy efficient	Using the most of energy without waste.	Changing energy from one form to another often results in energy lost as heat or sound. Efficiency is minimising this.
Gravitational potential energy	Energy that exists because of the difference in height between objects. Usually an object and the earth.	When an object is raised above the ground it has the potential to fall (*kinetic energy*). This potential is potential gravitational energy.
Thermal energy	Energy that exists as heat.	This is the energy we use to stay warm but it is also often generated when it isn't wanted due to inefficiency. A cars engine heats up because of this, rather than using all the energy in the fuel as *kinetic energy.*
Energy:		
Angle	The space between two lines that join at one end.	
Anticlockwise/ Clock-wise	Spins to the left, in the opposite way to a clock. Spins to the right like a clock.	
Equally	Having the same amount as another.	
Factors	Something that contributes to a result.	
Hexagon	A six-sided shape.	