**Playground Physics Unit Plan Rationale**

The "Physics in the Playground" unit plan (Appendix A) contains seven lessons designed to increase conceptual understanding of energy, force, and momentum, and follows the 5Es model (Bybee, 1997). The unit follows a natural progression: after the initial engagement and diagnostic assessment, the unit continues with three "Explore" lessons: first, an exploration of forces in equilibrium, framed in the context of "balancing". Next, we present a hands-on inquiry of friction, the all-pervasive real-world phenomenon that slows motion and influences alternate conceptions of motion and force. The third "Explore" lesson (Lesson 4) addresses momentum. Equipped with the "Explore" conceptual tools, the student progresses to the "Explain" and "Elaborate" Stages, involving design and open guided inquiries related to the unit's curriculum conceptual and process goals. The final lesson offers the student the opportunity to demonstrate learning with a creative design project of a new piece of playground equipment.

**Context of Unit Plan**

The unit is designed to fit into the "energy and force" strand of the Tasmanian Curriculum: Science for upper primary (Standard 3, Stages 7-9). Prior knowledge of gravitational forces is assumed, as prescribed in Stage 4 of the Tasmanian Curriculum: Science (p. 42). The unit can be coordinated with Stage 8 Earth and space curriculum goal on gravity ("investigate the effects of gravity as the force that causes objects to fall towards the Earth")(p. 66) which ideally introduces the concept of inertia. Other "prerequisites" include fundamental scientific notions of energy (Standard 2 of the Tasmanian Curriculum: Science). The unit focuses on linear motion and all vector qualities of force are aligned in the direction of motion. The unit avoids rotational phenomena to demonstrate force and motion, which can be misconstrued at this level due to the interplay of friction and moment of inertia effects. The unit is designed as a conceptual foundation to the subsequent formal study of Newton's laws (Tasmanian Curriculum: Science, Stage 14). The unit integrates with lessons in the Standard 3 math curriculum-- "Exposing students to a range of ways to record data and developing their confidence to independently or collaboratively construct different graphs and charts to suit a purpose (Tasmanian Curriculum: Math, 2007, p. 45). In lesson 2, there is also opportunity to integrate with the Tasmanian Curriculum: History, Standard 3--interactions with the environment.

**Conceptual links to Tasmanian Curriculum**

For the behaviour of forces, Lesson 2 (static equilibrium) is directly linked to the Stage 8 outcome, "recognise positioning to balance different masses on a see-saw" (Tasmanian Curriculum: Science, p. 117). The formative assessment is based on the understanding of balanced forces; specifically, how a gravitational force on a static object is opposed by an equal and opposite force. Lesson 3 has two differentiated outcomes related to friction: "predicting and recording which surface has the least friction in an investigation" (Stage 6)(p. 40), and "identifying friction as a force that opposes motion" (Stage 10) (p. 117). The transfer of energy from kinetic to thermal is also introduced in this lesson to introduce conservation of energy concepts. The lesson's assessment relates to specific identification of frictional effects. Lesson 4 lesson and assessment primarily relates to a Stage 8 outcome "compare effects of ...forces" (p. 117) and underpins the conceptual understanding of the overall conceptual goal on the nature of forces and motion. Lesson 5, the design of a playground slide, is based on the Stage 9 outcome of "describing some of the relationships that exist between force, motion, and energy" (p. 117) and is formatively assessed based on the ability to represent forces both in terms of magnitude and direction. Lesson 6 is specified as a Standard 3 outcome, "predicting, testing, analysing, and reporting on how the swing of a pendulum is affected by the length of the string and the weight of the pendulum" (p. 86) and is summatively assessed on these criteria. Finally, lesson 7 is the summative assessment of the conceptual understanding of the scientific principles of force, energy, and momentum and examines the student's ability to demonstrate, identify, evaluate, predict, and generalise the forces and motion in their creative design.
Throughout the unit plan, each student reviews and revises an individual TWLH chart that encourages the use of drawings, as "children's drawings are particularly useful in conveying their ideas." (Harlen & Qualter, 2009, p. 75). The TWLH charts also highlight the "before views" with the "after views" (Hanifi, Donald & Zeegers, 2003), and are scaffolded with open questioning throughout the unit.

The lessons incorporate hands-on activities and cater for a diverse range of students. For example, in lesson 2, the conceptual goal is to gain an understanding of stability through the balance of forces. The scaffolding prescribed includes advanced concepts, but aims to, as Skamp describes, "gain an understanding of what affected the stability of such structures without recourse to advanced ideas such as centre of gravity (Skamp, 1998, p. 98). In the lesson, the teacher provides a short demonstration, which finds the centre of gravity of a cut-out piece of cardboard using the quick and simple procedure of drawing plumblines on the amorphous two dimensional shape as it is hung from various random points. The technical knowledge and understanding of centre of gravity is not prescribed; however, the student observes the discovery of a point on the shape with special properties--the shape balances on that point. The intuitive experience of balance is then linked to the conceptual goals of forces in equilibrium.

In lesson 3, friction is specifically addressed. The failure to conceptually isolate frictional effects is one of the "key difficulties" in the comprehension of classical mechanics (Skamp, p. 96). The lesson begins with a diagnostic assessment of why motion slows, which is segued into a formal study of static friction which compares a brick's gravitational force with the force required to pull it along a flat surface using various materials between the table and the brick (Skamp, p. 95). After the study, the lesson ends with a hands-on example with a sliding wood block converting kinetic energy to thermal energy. Friction is a difficult concept, and "it takes a leap of imagination to be convinced that a brick would keep going steadily across a floor if it weren't for frictional effects" (Skamp, 97). By examining specific examples of varying degrees of friction, the lesson's goal is to make the leap more accessible. "The more personal and practical the involvement, the greater the potential for learning." (Dawson & Venville, 2007, p. 113).

**Rationale for including momentum**

Although momentum is not specifically specified in either the Tasmanian or the Australian Curriculum[1], it is a fundamental concept intimately linked to classical analyses of motion and force. "We must start where the child is" (Osborne, 1982). A primary alternate conception in the study of motion is "to think of a force as a property of something that is moving" (Fleer, Jane & Hardy, 2007, p. 59). The prevalence of the idea that "motion implies a force" (Clement, 1982) is unsurprising, as prior to Galileo, the common Aristotelian 'intuition' could be described as F=mv (force is proportional to velocity). However, the common version of Newton's second law (F=ma) encourages a focus on acceleration--the second derivative of position and conceptually difficult. Studies[2] indicate there is a "widespread incidence" (Kruger, Summers & Palacio, 1990, p. 93) of teacher's misconceptions of motion and force. The difficulty is in the comprehension and application

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[1] The first appearance of the term "momentum" in the Australian Curriculum is as an assessment criterion in a Year 10 Work Sample. Thus it is assumed, yet not explicitly part of any year's curriculum.

[2] See also Kikas, 2004.

of Newton's second law. In fact, Newton did not use the term 'acceleration' in his second law, but rather described "the alteration of motion" as proportional to the "force impressed" (Newton, 1729, p. 19). In his introductory definitions (ibid, p. 2), Newton describes the "quantity of motion" as the measure of mass and velocity--momentum in today's scientific terminology. Thus, Newton's second law can be expressed, in quantitative terms, "the change in momentum is proportional to the force impressed". Not only is this the original scientific postulate describing motion's link to force (Ellis, 1962, p. 274), but also it reveals a path to aid scientific understanding in today's classroom. The alternate conception of "motion implying a force" is common in this age group and arises from the confusion between momentum and force (Tytler, 2002); thus, in accordance with Osborne, we can begin the construction (and distinction from force) of the scientific understanding of momentum in scalar terms. The concept of impulse interconnects with momentum. Impulse is the application of a force over time and can be represented as "F x t" for a constant force (note: the equations described here are to justify logic within the sequence and would *not* be part of the lessons). The momentum-based linear interpretation of Newton's second law can thus be expressed[3]: $F \times t = \Delta mv$. Impulse[4] relates to common experiences, such as kicking a ball (it is readily apparent that a kick is a force being applied for a short period of time). Throwing a ball could also be examined in the momentum-impulse framework and is a component of Stage nine understanding: "investigate and describe some of the relationships that exist between force, motion, and energy, e.g. ... throwing a ball" (Tasmanian Curriculum: Science, p. 85). With today's accessible ICT tools (Appendix D), students can now visualise a force being applied over a fraction of a second (the impulse) and see the resulting change in velocity. It could be argued that, unlike the term "force"[5], the everyday meanings of momentum and impulse are more closely related to their scientific definitions and thus less likely to be misinterpreted. This unit plan incorporates the scientific use of momentum to quantify an object's motion.

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[3] Also inferred from common form: $F=ma \dashrightarrow F=\Delta mv/t$ (assumes constant acceleration,i.e. no 3rd order jerk).

[4] The teaching of impulse (F x t) could be contrasted with the commonly taught examples of a continuous force applied over a distance (F x d). In "everyday life", a constant force applied over a distance primarily corresponds to the situation when frictional forces balance a pull/push force (velocity is constant), thus the focus on force over a distance can further misconceptions over the nature of force and its relationship to an object's velocity. Knowledge of the equation of impulse is not required to gain its conceptual understanding.

[5] Even the Tasmanian Curriculum: Science uses it imprecisely, e.g. "investigating the effect that changing the slope (increasing the force) of a ramp has on an object rolled down it" (p. 85). What force? The gravitational force is constant, and an analysis of the reaction forces of a rolling object is beyond Standard 3.

**Process Goals**

The process goal Scientific Inquiry process goal, "scientific inquiries are generated from observations, questions, and predictions" (Tasmanian Curriculum: Science, p. 115) is addressed formatively in lesson 3, with a POE (Predict, Observe, Explain) on the frictional properties of various materials, and summatively assessed in lesson 6, where the student is asked to create a fair test of a pendulum variable using the Cows Moo Softly technique and the worksheet from the Western Australia Department of Education in Appendix C (Hacking, 2005). The Scientific Communication goal, "Scientists need to communicate information in a variety of ways" (Tasmanian Curriculum: Science, p. 116) is formatively assessed in lesson 3 on the results of the scientific investigation on friction, and in lesson 5 on the presentation of the slide design, and summatively assessed in the final lesson on the presentation of the playground equipment design where the student is asked to reason using scientific terms, and back up claims with evidence. The assessment involves sharing the design with the class, placed in a context of collaborative brainstorming peer assessment; instead of a critique, other students could assist in finding other ways energy, force, and momentum are incorporated in the design. A rating rubric on energy and force (Skamp, 1998) is provided at the end of the unit plan.

**Management and Safety**

The unit can be adapted to various abilities by group management. Activities are performed individually and in small groups, with a basis on cooperation and inclusiveness. Monitoring all group work is prescribed. Safety considerations are noted in the unit plan, as "learning to use materials and equipment is central to working scientifically." (Primary Connections, 2010, p. x). Prior to each lesson, cautioning students on potential dangers, with a routine of setting up and putting away at the start and end of each lesson.

**Conclusion**

The unit "Physics in the Playground" is designed to promote the development of scientific literacy. The hands-on activities, inquiry, and student communication reinforce the combination of conceptual and process learning goals. Presenting activities based on scientific theory without exposing the deeper mathematical logic, the unit is designed to lay the groundwork for the formal operational thinking, beginning to develop with students at this age (Peterson, 2010), of the relationship between forces and motion.

## References

*Australian Curriculum.* (2011). Australian Curriculum, Assessment and Reporting Authority Retrieved from: http://www.australiancurriculum.edu.au/Science/Curriculum/F-10

Bybee, R.W. 1997. *Achieving Scientific Literacy*. Portsmouth, N.H.: Heinemann.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Association of Physics Teachers,* 50(1).

Dawson, V. & Venville, G. (Eds.). (2007). *The art of teaching primary science.* NSW, Australia: Allen & Unwin.

Ellis, B. (1962). Newton's concept of motive force. *Journal of the history of ideas. 23*(2), pp. 273-278.

Fleer, M., Jane, B., Hardy, T. (2007). *Science for children: Developing a personal approach to teaching.* NSW: Pearson Education Australia.

Hackling, M. (2005). *Working scientifically: Implementing and assessing open investigation work in science.* Western Australia: Department of Education and Training.

Hanifi, H., Donald, K. & Zeegers, Y. (2002). Planning a unit of work: incorporating students' questions. *Investigating 19*(1).

Harlen, W., Qualter, A. (2009). *The teaching of science in primary schools (5th ed.).* Oxon, Canada: Routledge.

Kikas, E. (2004).Teachers' Conceptions and Misconceptions Concerning Three Natural Phenomena. *Journal of research in science teaching 41(5)*, pp. 432-448.

Kruger, C. ,Summers, M. & Palacio, P. (1990). A survey of primary school teachers' conceptions of force and motion. *Educational Research, 32 (2)* pp. 83-95.

Kibble, B. (2006, May). Understanding forces: what's the problem? *Physics Education 41* (3) pp. 228-231.

Newton, I. (1729). *The mathematical principles of natural philosophy, Volume 1.* (English translation based on 3rd Latin edition). Retrieved from http://books.google.com.au

Osborne, R. (1982). Science Education: Where do we start? *The Australian Science Teachers Journal, 28*(1).

Peterson, C. (2010). *Looking forward through the lifespan: Developmental psychology, 5th ed. NSW:* Frenchs Forest. p. 286.

Primary Conncetions (2010). *Smooth moves: Stage 2: Energy and Change.* ACT: Australian Academy of Science

Skamp, K. (1998). *Teaching primary science constructively.* Victoria, Australia: Cengage Learning.

*Tasmanian Curriculum: Science.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/science/syl-scienceall.pdf

*Tasmanian Curriculum: Math.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/maths

*Tasmanian Curriculum: Society and History.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/society

Tytler, R. (2002). Teaching for understanding in science: Constructivist/conceptual change teaching approaches. *Australian Science Teachers Journal, 48*(4), pp. 30-35.

APPENDIX A: UNIT PLAN

| **UNIT TITLE** | **PHYSICS IN THE PLAYGROUND** |
|---|---|
| **Description** | Students will investigate the physical forces on a variety of playground equipment to build their understanding of energy, forces, and momentum. |
| **Curriculum Objectives and Context** | Tasmanian Curriculum: Science Standard 3, Stages 7-9 (Year 6).<br>•Science as a body of knowledge--energy and force<br>•Scientific Inquiry (plan, predict, observe, interpret)<br>•Scientific Communication |
| **Assessment Strategies** | Diagnostic: Assessment of prior understandings.<br>Formative: Informal assessments throughout.<br>Summative: Investigative worksheet and final design project. |
| **Conceptual Goals** | ***Force:*** Forces can be either opposed or unopposed; a net force on an object results in a change of velocity. Forces can be direct (e.g. push/pull, friction), or indirect (e.g. gravity).<br>***Energy***: Kinetic energy can be transformed to thermal energy.<br>***Momentum***: The momentum of an object is changed by the application of a force for a period of time. |
| **Process Goals** | ***Scientific Inquiry***: Plan and conduct investigations related to energy, forces and movement in the playground.<br>***Scientific Communication***: Describe using drawings and description a design for a new piece of playground equipment using scientific concepts and terminology related to energy, force, and movement. |

| **Lesson 1 (Engage): Build and analyse model of playground equipment** | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage<br>(10 minutes)<br>Whole class | •Describe overall playground physics unit plan combined with a visit to the playground. | |
| 2. Interact<br>(30 minutes)<br>Small groups | •Students use materials to build a model of a chosen playground feature with provided materials (popsicle sticks, tissue tubes, dowels, pipe cleaners, playdough, string, straws, manila paper, cardboard, scissors, glue, tape, etc.) | Box of building materials per group. |
| 3. Reflect<br>(15 minutes)<br>Whole class | •Discuss each model in terms of forces, movement, and energy using student language (i.e. ask: "How does it work?" "What makes it move?" "Is there energy involved?").<br>•*Diagnostic assessment:*<br>1.Student identifies forces as opposed or unopposed, direct or indirect.<br>2.Student distinguishes forces that create movement.<br>3.Students can identify forms energy.<br>•Distribute TWLH charts to each student and provide time for TW completion.<br>•Begin Word Wall for new terms. | •TWLH chart for each student. (Appenidx B)<br>•Word Wall.<br><br>Throughout lesson, refer to and update TWLH and Word Wall when appropriate. |

| **Lesson 2 (Explore): Static equilibrium and levers.** | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage<br>(12 minutes)<br>Whole class | •Quickly build interesting balance "sculpture".<br>•Ask: How do we balance? What are the forces?<br>•Find centre of gravity for odd-shapes of cardboard by hanging from pin and drawing plumbline. The intersection of two or three of such plumblines will be the CG--shape will spin freely around CG.<br>•POE: Two students balance a yardstick--each one has one finger on the yardstick. What happens when one slides their finger toward the other? Where will their fingers end up? (in the middle).<br>•Video of Easter Island showing use of lever (integration with Tasmanian Curriculum: History, Standard 3--interactions with the environment). | •Corks, two forks, toothpick, bottle.<br>•Cardboard, plumb-bob, marker.<br><br>www.teachersdomain.org/resource/phy03.sci.phys.energy.moai/ |

| Lesson 2 (Explore): Static equilibrium and levers. | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 2. Interact (25 minutes) Small groups | •Investigate levers and moment-of-force (torque): Student holds long broom handle with increasing weights on end.<br>•Experiment with balancing model see-saws.<br>•Pose problem: design a see-saw for a 1 kg cat and a 2 kg dog--investigate the relationship between mass and distance from fulcrum. | •Broom handle, weights.<br><br>•Flat boards (33cm x 5cm), wood prisms (fulcrums), blocks. |
| 3. Reflect (5 minutes) | *Formative Assessment:*<br>•Student understands that for an object in static equilibrium, gravitational forces are opposed by other forces (e.g. the table exerts a upward force on a book--scaffold with "mattress model" (Kibble, 2006) if necessary). | |

| Lesson 3 (Explore): Frictional forces on flat surfaces | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (3 minutes) | Slide wood block across table.<br>Ask: Why does it stop?<br>Record answers on board and assess alternate conceptions. | Smooth wood block. |
| 2. Interact (30 minutes) Small group activity with individual friction charts in science books. | •Introduce concept of Newton as measure of force and relate to common objects (e.g. apple=1N).<br>•POE (predict, observe, explain): Student predicts the frictional effects of different materials.<br>•On flat surfaces, student investigates static friction with Newton-meter using various materials.<br>•Student compares weight of brick measured with Newton meter (gravitational force) with force required to overcome static friction using various materials between brick and table.<br>•Student sketches experiment and creates chart: material, weight, pull force, and ratio of pull force/normal force (normal force=weight in this case; thus, this ratio is the coefficient of friction). Introduce force diagrams to describe forces.<br>•Ask: what happens to the energy of object slowed by friction? Have students slide wood block back and forth on a floor for a few minutes, then feel the temperature of the block (Ensure safety by choosing responsible students to do experiment). | Newton meters, bricks and various flat materials: sandpaper, aluminium foil, plastic, fabric.<br><br>Science journals |

| Lesson 3 (Explore): Frictional forces on flat surfaces | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 3. Reflect<br>(7 minutes) | *Formative assessment--frictional forces:*<br>•Student identifies materials with lower/higher coefficient of friction.<br>•Student understands frictional forces slow moving objects; kinetic energy converts to thermal energy.<br>•Process: Student makes predictions with some scientific basis.<br>•Process: Student presents findings in an organised way with a sketch. | |

| Lesson 4 (Explore): Momentum and Impulse. | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage<br>(8 minutes) | •Drop basketball with softball directly on top (softball rebounds much higher).<br>•Brainstorm concept of momentum--> a function of an object's mass and velocity. | Basketball and softball. |
| 2. Interact<br>(45 minutes)<br>Small groups | •Create roles (Speaker/Manager/Director) for outdoor student activity: using iPad/iPhone software 'Video Physics', record kicking of ball and process.<br>•Student examines time of impulse and compares with horizontal velocity for 'Standard' kicks (example: http://www.deuce4.net/web/videoPhysics.m4v).<br>•Show baseball video segment and brainstorm other sporting activities involving forces acting over a period of time that result in a change of momentum. | http://www.vernier.com/products/software/video-physics/<br><br>http://www.teachersdomain.org/resource/kqed09.sci.phys.maf.kqedbaseball/ |
| 3. Reflect<br>(7 minutes) | *Formative assessment:*<br>•Student recognises that a force applied over a period of time changes the velocity of an object (Teacher understanding: $F \times t = \Delta mv$). | |

| Lesson 5 (Explain): Design of Playground Slide | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage<br>(15 minutes) | Continue with Force Diagrams with direct instruction, examples, and questioning. | |

| Lesson 5 (Explain): Design of Playground Slide | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 2. Interact (30 minutes) Guided design process | •Student designs playground slide for small children to ensure sliding at a slowest possible speed.<br>•Brainstorm design variables (angle), constrain shape to linear slide (ramp).<br>•Provide sample clothing material and plastic material for slide; students wrap block with fabric and calculate coefficient of friction (lesson 3).<br>•Student uses PhET resource to find ideal angle[1].<br>•Student sketches final design in Science Journal with force diagram.<br>[1] Integration: alternatively, this could be math lesson on right angles; answer can be derived graphically. | Plastic strips, fabric swatches, heavy blocks, Newton meter.<br><br>http://phet.colorado.edu/en/simulation/ramp-forces-and-motion<br><br>Science Journals |
| 3. Reflect (5 minutes) | *Formative Assessment:*<br>•Student describes directional aspect of gravitational force, frictional force.<br>•Student represents magnitude of force by the relative length of force diagram arrows.<br>•Process: Student composes results clearly and logically. | |

| Lesson 6 (Elaborate): Design of Playground Swing | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (10 minutes) | •Outdoors, select students to see who can do the most swings in 10 seconds (the swing's resonant frequency results in no clear 'winner').<br>•Back in class, open questioning on pendulums. | Playground swing. |
| 2. Interact (40 minutes) | •Design of swing modelled as pendulum.<br>•Question: "How can we change the period?"<br>•Fair test: scaffold "Cows Moo Softly" (Change, Measure, Same) and brainstorm variables (mass, length of string, initial 'push', initial angle of release). | String, weights, measuring tools.<br><br>Investigative Worksheet (Appendix C) |
| 3. Reflect (10 minutes) | •*Summative Assessment: Investigative Worksheet*<br>•Student plans and implements fair test.<br>•Student concludes correct effect of tested variable.<br>•Student recognises differences and/or similarities between prediction and result.<br>•Student's work uses scientific terminology.<br>•Student's work is neat and presentable. | |

| **Lesson 7 (Evaluate): Design of new Playground Equipment** | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |

| **Lesson 7 (Evaluate): Design of new Playground Equipment** | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (5 minutes) | Announce and discuss design project. | |
| 2. Interact (30 minutes) | •In groups or individually, students sketch and describe design of a new piece of playground equipment that involves movement. Energy, forces, and momentum are identified (where applicable). Explain that the design will be marked, and provide the basis for assessment (below) to students. | |
| 3. Reflect (45 minutes) | Students present design project to class.<br>*Summative Assessment:*<br>• Student demonstrates movement in design.<br>• Student identifies forces that affect movement.<br>• Student evaluates effects of other direct and indirect forces.<br>• Student predicts effects of friction in design.<br>• Student generalises other possible energy transformations in design.<br>• Student reasons with appropriate scientific terms, and backs up claims with evidence.<br>• Design is neatly presented.<br>•Design is safe. | |

RUBRIC FOR SUMMATIVE CONCEPTUAL DESIGN (derived from Skamp, 1998, p. 103-104)
Level 1 Student can describe simple situations involving movement and force usign appropriate terminology, such as "push", "pull, "speeding up". Can make sensible observations of a variety of movments using appropriate simple language."
Level 2 Can make observations about movement and force situations and generate interpretations based on patterns, such as "heavy things need more force to move". Uses the language of push and pul, but may harbour varied notions of forces resideing in moving objects and has confused ideas about gravity and friction.
Level 3 Can describe a variety of motions in detailed terms and can attempt reasonable explanations of different motions in terms of the actions of forces of different types (gravity, friction, forces due to air, pushes and pulls). Has a basic understanding of gravity. May still harbour a variety of alternate conceptions.
Level 4 Can describe motion in specific terms, such as "speeding up", "slowing down". Can describe the effects of combinations of forces to affect an object's motion in situations where they may oppose or where an object is balnacing under the action of different forces. Can attempt interpretation of complex motions in terms of detailed consideration of different forces.

APPENDIX B: TWLH CHART (for each student)

TWLH Chart (Think, Want, Learn, How) Name:_________________

| **What I *think* I know about movement in the playground** | **What I *want* to know about movement in the playground** |
|---|---|
| in words: | in words: |
| draw a picture: | draw a picture: |
| **What I *learned* about movement in the playground** | ***How* I know it** |
| in words: | in words: |
| draw a picture: | draw a picture: |

APPENDIX C: Investigation Worksheet
(Source: Working Scientifically, Hackling, 2005)

## Planning and Report Worksheet for Science Investigations

Student name ______________________________ Class ______________

Other members of your group ________________________________________

What are you going to investigate?

What do you think will happen? Explain why.

Which variables are you going to:

- change?
- measure?
- keep the same?

How will you make it a fair test?

What equipment will you need?

What happened? Describe your observations and record your results.

Can your results be presented as a graph?

What do your results tell you? Are there any relationships, patterns or trends in your results?

Can you explain the relationships, patterns or trends in your results? Try to use some science ideas to help explain what happened?

What did you find out about the problem you investigated? Was the outcome different from your prediction? Explain.

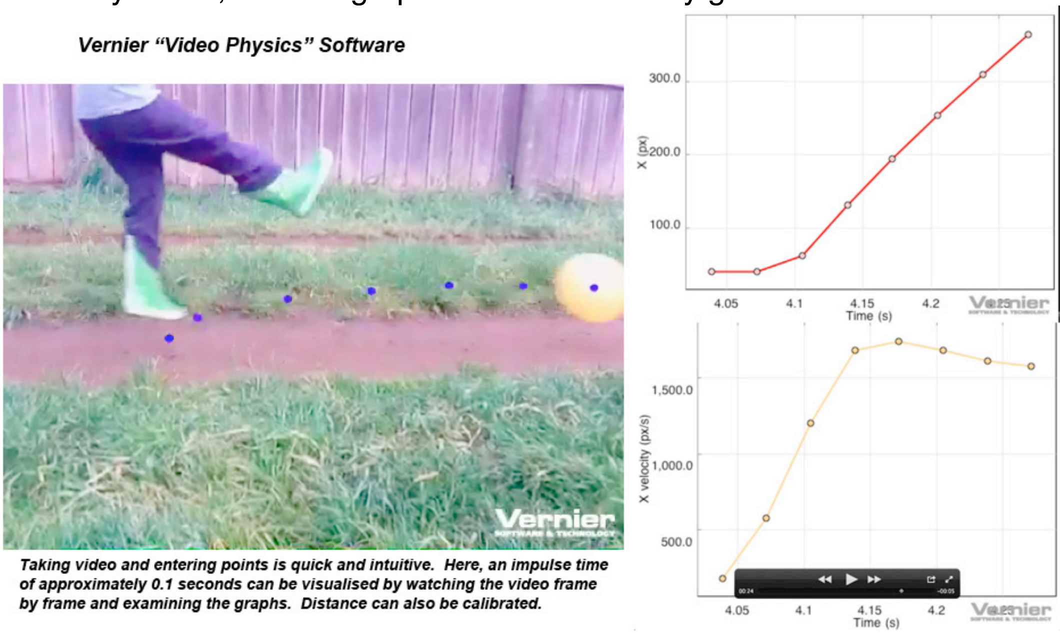
What difficulties did you experience in doing this investigation?

How could you improve this investigation, for example, fairness, accuracy?

Appendix D: ICT resources.

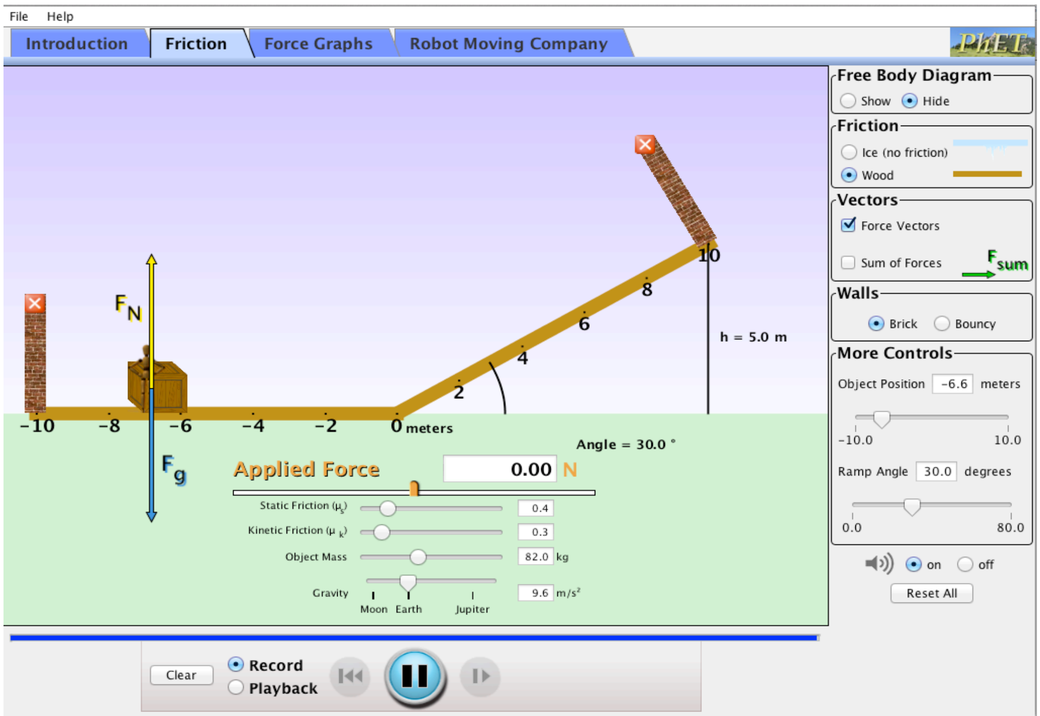
**Lesson 4:  Vernier 'Video Physics' Software for iPhone/iPad**
This software is inexpensive ($2.99) and can be used to roughly estimate (more importantly, to visualise) the time of impact.  This can help students understand the link between forces, time, and changes in momentum and dispel the alternate conception of force "becoming" part of the motion. The points take seconds to add frame by frame, and the graphs are automatically generated.

*Vernier "Video Physics" Software*




*Taking video and entering points is quick and intuitive.  Here, an impulse time of approximately 0.1 seconds can be visualised by watching the video frame by frame and examining the graphs.  Distance can also be calibrated.*

## Lesson 5: Phet Simulation




Steps: 1. Click "Friction" tab (http://phet.colorado.edu/en/simulation/ramp-forces-and-motion)
2. Set "Static friction" to design value.
3. Use "Object Position" and run/stop button to perform tests.
4. Change "Ramp Angle" to determine minimum.

**Playground Physics Unit Plan Rationale**

The "Physics in the Playground" unit plan (Appendix A) contains seven lessons designed to increase conceptual understanding of energy, force, and momentum, and follows the 5Es model (Bybee, 1997). The unit follows a natural progression: after the initial engagement and diagnostic assessment, the unit continues with three "Explore" lessons: first, an exploration of forces in equilibrium, framed in the context of "balancing". Next, we present a hands-on inquiry of friction, the all-pervasive real-world phenomenon that slows motion and influences alternate conceptions of motion and force. The third "Explore" lesson (Lesson 4) addresses momentum. Equipped with the "Explore" conceptual tools, the student progresses to the "Explain" and "Elaborate" Stages, involving design and open guided inquiries related to the unit's curriculum conceptual and process goals. The final lesson offers the student the opportunity to demonstrate learning with a creative design project of a new piece of playground equipment.

Jill 24/10/11 7:58 AM
**Comment [1]:** Good to see someone referencing the 5 Es correctly.

Jill 24/10/11 7:59 AM
**Comment [2]:** How will you approach this segment?

Jill 24/10/11 7:59 AM
**Comment [3]:** Terrific idea

**Context of Unit Plan**

The unit is designed to fit into the "energy and force" strand of the Tasmanian Curriculum: Science for upper primary (Standard 3, Stages 7-9). Prior knowledge of gravitational forces is assumed, as prescribed in Stage 4 of the Tasmanian Curriculum: Science (p. 42). The unit can be coordinated with Stage 8 Earth and space curriculum goal on gravity ("investigate the effects of gravity as the force that causes objects to fall towards the Earth")(p. 66) which ideally introduces the concept of inertia. Other "prerequisites" include fundamental scientific notions of energy (Standard 2 of the Tasmanian Curriculum: Science). The unit focuses on linear motion and all vector qualities of force are aligned in the direction of motion. The unit avoids rotational phenomena to demonstrate force and motion, which can be misconstrued at this level due to the interplay of friction and moment of inertia effects. The unit is designed as a conceptual foundation to the subsequent formal study of Newton's laws (Tasmanian Curriculum: Science, Stage 14). The unit integrates with lessons in the Standard 3 math curriculum-- "Exposing students to a range of ways to record data and developing their confidence to independently or collaboratively construct different graphs and charts to suit a purpose (Tasmanian Curriculum: Math, 2007, p. 45). In lesson 2, there is also opportunity to integrate with the Tasmanian Curriculum: History, Standard 3--interactions with the environment.

Jill 24/10/11 8:01 AM
**Comment [4]:** But would be checked – at least in terms of the term itself – remember how prevalent alternative conceptions can be.

Jill 24/10/11 8:02 AM
**Comment [5]:** Once again this would be part of your diagnostic assessment

Jill 24/10/11 8:02 AM
**Comment [6]:** Expand ?

**Conceptual links to Tasmanian Curriculum**

For the behaviour of forces, Lesson 2 (static equilibrium) is directly linked to the Stage 8 outcome, "recognise positioning to balance different masses on a see-saw" (Tasmanian Curriculum: Science, p. 117). The formative assessment is based on the understanding of balanced forces; specifically, how a gravitational force on a static object is opposed by an equal and opposite force. Lesson 3 has two differentiated outcomes related to friction: "predicting and recording which surface has the least friction in an investigation" (Stage 6)(p. 40), and "identifying friction as a force that opposes motion" (Stage 10) (p. 117). The transfer of energy from kinetic to thermal is also introduced in this lesson to introduce conservation of energy concepts. The lesson's assessment relates to specific identification of frictional effects. Lesson 4 lesson and assessment primarily relates to a Stage 8 outcome "compare effects of ...forces" (p. 117) and underpins the conceptual understanding of the overall conceptual goal on the nature of forces and motion. Lesson 5, the design of a playground slide, is based on the Stage 9 outcome of "describing some of the relationships that exist between force, motion, and energy" (p. 117) and is formatively assessed based on the ability to represent forces both in terms of magnitude and direction. Lesson 6 is specified as a Standard 3 outcome, "predicting, testing, analysing, and reporting on how the swing of a pendulum is affected by the length of the string and the weight of the pendulum" (p. 86) and is summatively assessed on these criteria. Finally, lesson 7 is the summative assessment of the conceptual understanding of the scientific principles of force, energy, and momentum and examines the student's ability to demonstrate, identify, evaluate, predict, and generalise the forces and motion in their creative design. Throughout the unit plan, each student reviews and revises an individual TWLH chart that encourages the use of drawings, as "children's drawings are particularly useful in conveying their ideas." (Harlen & Qualter, 2009, p. 75). The TWLH charts also highlight the "before views" with the "after views" (Hanifi, Donald & Zeegers, 2003), and are scaffolded with open questioning throughout the unit.

Jill 24/10/11 8:03 AM
**Comment [7]:** Material?

Jill 24/10/11 8:05 AM
**Comment [8]:** An interesting slant on a TWLH chart

The lessons incorporate hands-on activities and cater for a diverse range of students. For example, in lesson 2, the conceptual goal is to gain an understanding of stability through the balance of forces. The scaffolding prescribed includes advanced concepts, but aims to, as Skamp describes, "gain an understanding of what affected the stability of such structures without recourse to advanced ideas such as centre of gravity (Skamp, 1998, p. 98). In the lesson, the teacher provides a short demonstration, which finds the centre of gravity of a cut-out piece of cardboard using the quick and simple procedure of drawing plumblines on the amorphous two dimensional shape as it is hung from various random points. The technical knowledge and understanding of centre of gravity is not prescribed; however, the student observes the discovery of a point on the shape with special properties--the shape balances on that point. The intuitive experience of balance is then linked to the conceptual goals of forces in equilibrium.

Jill 24/10/11 8:06 AM
**Comment [9]:** I look forward to seeing how in your plan you indicate how this caters for diversity!

In lesson 3, friction is specifically addressed. The failure to conceptually isolate frictional effects is one of the "key difficulties" in the comprehension of classical mechanics (Skamp, p. 96). The lesson begins with a diagnostic assessment of why motion slows, which is segued into a formal study of static friction which compares a brick's gravitational force with the force required to pull it along a flat surface using various materials between the table and the brick (Skamp, p. 95). After the study, the lesson ends with a hands-on example with a sliding wood block converting kinetic energy to thermal energy. Friction is a difficult concept, and "it takes a leap of imagination to be convinced that a brick would keep going steadily across a floor if it weren't for frictional effects" (Skamp, 97). By examining specific examples of varying degrees of friction, the lesson's goal is to make the leap more accessible. "The more personal and practical the involvement, the greater the potential for learning." (Dawson & Venville, 2007, p. 113).

**Rationale for including momentum**

Although momentum is not specifically specified in either the Tasmanian or the Australian Curriculum[1], it is a fundamental concept intimately linked to classical analyses of motion and force. "We must start where the child is" (Osborne, 1982). A primary alternate conception in the study of motion is "to think of a force as a property of something that is moving" (Fleer, Jane & Hardy, 2007, p. 59). The prevalence of the idea that "motion implies a force" (Clement, 1982) is unsurprising, as prior to Galileo, the common Aristotelian 'intuition' could be described as F=mv (force is proportional to velocity). However, the common version of Newton's second law (F=ma) encourages a focus on acceleration--the second derivative of position and conceptually difficult. Studies[2] indicate there is a "widespread incidence" (Kruger, Summers & Palacio, 1990, p. 93) of teacher's

Jill 24/10/11 8:15 AM
**Comment [10]:** Post reading I see the rationale for presenting the idea – but is this the ideal age?

[1] The first appearance of the term "momentum" in the Australian Curriculum is as an assessment criterion in a Year 10 Work Sample. Thus it is assumed, yet not explicitly part of any year's curriculum. it would be addressed post year 10 – it is interesting that it is not explicit before then.

[2] See also Kikas, 2004.

misconceptions of motion and force. The difficulty is in the comprehension and application of Newton's second law. In fact, Newton did not use the term 'acceleration' in his second law, but rather described "the alteration of motion" as proportional to the "force impressed" (Newton, 1729, p. 19). In his introductory definitions (ibid, p. 2), Newton describes the "quantity of motion" as the measure of mass and velocity--momentum in today's scientific terminology. Thus, Newton's second law can be expressed, in quantitative terms, "the change in momentum is proportional to the force impressed". Not only is this the original scientific postulate describing motion's link to force (Ellis, 1962, p. 274), but also it reveals a path to aid scientific understanding in today's classroom. The alternate conception of "motion implying a force" is common in this age group and arises from the confusion between momentum and force (Tytler, 2002); thus, in accordance with Osborne, we can begin the construction (and distinction from force) of the scientific understanding of momentum in scalar terms. The concept of impulse interconnects with momentum. Impulse is the application of a force over time and can be represented as "F x t" for a constant force (note: the equations described here are to justify logic within the sequence and would *not* be part of the lessons). The momentum-based linear interpretation of Newton's second law can thus be expressed[3]: $F \times t = \Delta mv$. Impulse[4] relates to common experiences, such as kicking a ball (it is readily apparent that a kick is a force being applied for a short period of time). Throwing a ball could also be examined in the momentum-impulse framework and is a component of Stage nine understanding: "investigate and describe some of the relationships that exist between force, motion, and energy, e.g. ... throwing a ball" (Tasmanian Curriculum: Science, p. 85). With today's accessible ICT tools (Appendix D), students can now visualise a force being applied over a fraction of a second (the impulse) and see the resulting change in velocity. It could be argued that, unlike the term "force"[5], the everyday meanings of momentum and impulse are more closely related to their scientific definitions and thus less likely to be misinterpreted. This unit plan incorporates the scientific use of momentum to quantify an object's motion.

[3] Also inferred from common form: $F=ma \dashrightarrow F=\Delta mv/t$ (assumes constant acceleration,i.e. no 3rd order jerk).

[4] The teaching of impulse (F x t) could be contrasted with the commonly taught examples of a continuous force applied over a distance (F x d). In "everyday life", a constant force applied over a distance primarily corresponds to the situation when frictional forces balance a pull/push force (velocity is constant), thus the focus on force over a distance can further misconceptions over the nature of force and its relationship to an object's velocity. Knowledge of the equation of impulse is not required to gain its conceptual understanding.

[5] Even the Tasmanian Curriculum: Science uses it imprecisely, e.g. "investigating the effect that changing the slope (increasing the force) of a ramp has on an object rolled down it" (p. 85). What force? The gravitational force is constant, and an analysis of the reaction forces of a rolling object is beyond Standard 3.

**Process Goals**

The process goal Scientific Inquiry process goal, "scientific inquiries are generated from observations, questions, and predictions" (Tasmanian Curriculum: Science, p. 115) is addressed formatively in lesson 3, with a POE (Predict, Observe, Explain) on the frictional properties of various materials, and summatively assessed in lesson 6, where the student is asked to create a fair test of a pendulum variable using the Cows Moo Softly technique and the worksheet from the Western Australia Department of Education in Appendix C (Hacking, 2005). The Scientific Communication goal, "Scientists need to communicate information in a variety of ways" (Tasmanian Curriculum: Science, p. 116) is formatively assessed in lesson 3 on the results of the scientific investigation on friction, and in lesson 5 on the presentation of the slide design, and summatively assessed in the final lesson on the presentation of the playground equipment design where the student is asked to reason using scientific terms, and back up claims with evidence. The assessment involves sharing the design with the class, placed in a context of collaborative brainstorming peer assessment; instead of a critique, other students could assist in finding other ways energy, force, and momentum are incorporated in the design. A rating rubric on energy and force (Skamp, 1998) is provided at the end of the unit plan.

**Management and Safety**

The unit can be adapted to various abilities by group management. Activities are performed individually and in small groups, with a basis on cooperation and inclusiveness. Monitoring all group work is prescribed. Safety considerations are noted in the unit plan, as "learning to use materials and equipment is central to working scientifically." (Primary Connections, 2010, p. x). Prior to each lesson, cautioning students on potential dangers, with a routine of setting up and putting away at the start and end of each lesson.

Jill 24/10/11 8:19 AM
**Comment [11]:** Sounds simple but usually need thought.

**Conclusion**

The unit "Physics in the Playground" is designed to promote the development of scientific literacy. The hands-on activities, inquiry, and student communication reinforce the combination of conceptual and process learning goals. Presenting activities based on scientific theory without exposing the deeper mathematical logic, the unit is designed to lay the groundwork for the formal operational thinking, beginning to develop with students at this age (Peterson, 2010), of the relationship between forces and motion.

Jill 24/10/11 8:20 AM
**Comment [12]:** Which is ....

**References**

*Australian Curriculum.* (2011). Australian Curriculum, Assessment and Reporting Authority Retrieved from: http://www.australiancurriculum.edu.au/Science/Curriculum/F-10

Bybee, R.W. 1997. *Achieving Scientific Literacy*. Portsmouth, N.H.: Heinemann.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Association of Physics Teachers,* 50(1).

Dawson, V. & Venville, G. (Eds.). (2007). *The art of teaching primary science.* NSW, Australia: Allen & Unwin.

Ellis, B. (1962). Newton's concept of motive force. *Journal of the history of ideas. 23*(2), pp. 273-278.

Fleer, M., Jane, B., Hardy, T. (2007). *Science for children: Developing a personal approach to teaching.* NSW: Pearson Education Australia.

Hackling, M. (2005). *Working scientifically: Implementing and assessing open investigation work in science.* Western Australia: Department of Education and Training.

Hanifi, H., Donald, K. & Zeegers, Y. (2002). Planning a unit of work: incorporating students' questions. *Investigating 19*(1).

Harlen, W., Qualter, A. (2009). *The teaching of science in primary schools (5th ed.).* Oxon, Canada: Routledge.

Kikas, E. (2004).Teachers' Conceptions and Misconceptions Concerning Three Natural Phenomena. *Journal of research in science teaching 41(5)*, pp. 432-448.

Kruger, C. ,Summers, M. & Palacio, P. (1990). A survey of primary school teachers' conceptions of force and motion. *Educational Research, 32 (2)* pp. 83-95.

Kibble, B. (2006, May). Understanding forces: what's the problem? *Physics Education 41* (3) pp. 228-231.

Newton, I. (1729). *The mathematical principles of natural philosophy, Volume 1.* (English translation based on 3rd Latin edition). Retrieved from http://books.google.com.au

Osborne, R. (1982). Science Education: Where do we start? *The Australian Science Teachers Journal, 28*(1).

Peterson, C. (2010). *Looking forward through the lifespan: Developmental psychology, 5th ed. NSW:* Frenchs Forest. p. 286.

Primary Conncetions (2010). *Smooth moves: Stage 2: Energy and Change.* ACT: Australian Academy of Science

Skamp, K. (1998). *Teaching primary science constructively.* Victoria, Australia: Cengage Learning.

*Tasmanian Curriculum: Science.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/science/syl-scienceall.pdf

*Tasmanian Curriculum: Math.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/maths

*Tasmanian Curriculum: Society and History.* (2007). Department of Education Tasmania. Retrieved from: http://www.education.tas.gov.au/curriculum/Standards/society

Tytler, R. (2002). Teaching for understanding in science: Constructivist/conceptual change teaching approaches. *Australian Science Teachers Journal, 48*(4), pp. 30-35.

APPENDIX A: UNIT PLAN

| **UNIT TITLE** | **PHYSICS IN THE PLAYGROUND** |
|---|---|
| **Description** | Students will investigate the physical forces on a variety of playground equipment to build their understanding of energy, forces, and momentum. |
| **Curriculum Objectives and Context** | Tasmanian Curriculum: Science Standard 3, Stages 7-9 (Year 6).<br>•Science as a body of knowledge--energy and force<br>•Scientific Inquiry (plan, predict, observe, interpret)<br>•Scientific Communication |
| **Assessment Strategies** | Diagnostic: Assessment of prior understandings.<br>Formative: Informal assessments throughout.<br>Summative: Investigative worksheet and final design project. |
| **Conceptual Goals** | ***Force:*** Forces can be either opposed or unopposed; a net force on an object results in a change of velocity. Forces can be direct (e.g. push/pull, friction), or indirect (e.g. gravity).<br>***Energy***: Kinetic energy can be transformed to thermal energy.<br>***Momentum***: The momentum of an object is changed by the application of a force for a period of time. |
| **Process Goals** | ***Scientific Inquiry***: Plan and conduct investigations related to energy, forces and movement in the playground.<br>***Scientific Communication***: Describe using drawings and description a design for a new piece of playground equipment using scientific concepts and terminology related to energy, force, and movement. |

| Lesson 1 (Engage): Build and analyse model of playground equipment | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (10 minutes) Whole class | •Describe overall playground physics unit plan combined with a visit to the playground. A question such as what makes a good piece of playground equipment might help set the scene. | |
| 2. Interact (30 minutes) Small groups | •Students use materials to build a model of a chosen playground feature with provided materials (popsicle sticks, tissue tubes, dowels, pipe cleaners, playdough, string, straws, manila paper, cardboard, scissors, glue, tape, etc.) | Box of building materials per group. |
| 3. Reflect (15 minutes) Whole class | •Discuss each model in terms of forces, movement, and energy using student language (i.e. ask: "How does it work?" "What makes it move?" "Is there energy involved?").<br>•*Diagnostic assessment:*<br>1.Student identifies forces as opposed or unopposed, direct or indirect.<br>2.Student distinguishes forces that create movement.<br>3.Students can identify forms energy.<br>•Distribute TWLH charts to each student and provide time for TW completion.<br>•Begin Word Wall for new terms. | •TWLH chart for each student. (Appendix B)<br>•Word Wall.<br><br>Throughout lesson, refer to and update TWLH and Word Wall when appropriate. |

| Lesson 2 (Explore): Static equilibrium and levers. | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (12 minutes) Whole class | •Quickly build interesting balance "sculpture".<br>•Ask: How do we balance? What are the forces?<br>•Find centre of gravity for odd-shapes of cardboard by hanging from pin and drawing plumbline. The intersection of two or three of such plumblines will be the CG--shape will spin freely around CG.<br>•POE: Two students balance a yardstick--each one has one finger on the yardstick. What happens when one slides their finger toward the other? Where will their fingers end up? (in the middle).<br>•Video of Easter Island showing use of lever (integration with Tasmanian Curriculum: History, Standard 3--interactions with the environment). | •Corks, two forks, toothpick, bottle.<br>•Cardboard, plumb-bob, marker.<br><br>www.teachersdomain.org/resource/phy03.sci.phys.energy.moai/ |

Jill 24/10/11 8:26 AM
**Comment [13]:** May not be long enough.

Jill 24/10/11 8:26 AM
**Deleted:** Appenidx

Jill 24/10/11 8:26 AM
**Comment [14]:** good

Jill 24/10/11 8:28 AM
**Comment [15]:** remember you would need to start where they are at – what do they understanding about force first?

Jill 24/10/11 8:29 AM
**Comment [16]:** Establish connection to your introductory lesson

| Lesson 2 (Explore): Static equilibrium and levers. | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 2. Interact (25 minutes) Small groups | •Investigate levers and moment-of-force (torque): Student holds long broom handle with increasing weights on end.<br>•Experiment with balancing model see-saws.<br>•Pose problem: design a see-saw for a 1 kg cat and a 2 kg dog--investigate the relationship between mass and distance from fulcrum. | •Broom handle, weights.<br><br>•Flat boards (33cm x 5cm), wood prisms (fulcrums), blocks. |
| 3. Reflect (5 minutes) | *Formative Assessment:*<br>•Student understands that for an object in static equilibrium, gravitational forces are opposed by other forces (e.g. the table exerts a upward force on a book--scaffold with "mattress model" (Kibble, 2006) if necessary). | |

Jill 24/10/11 8:29 AM
**Comment [17]:** Lovely – a good idea

| Lesson 3 (Explore): Frictional forces on flat surfaces | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (3 minutes) | Slide wood block across table.<br>Ask: Why does it stop?<br>Record answers on board and assess alternate conceptions. | Smooth wood block. |
| 2. Interact (30 minutes) Small group activity with individual friction charts in science books. | •Introduce concept of Newton as measure of force and relate to common objects (e.g. apple=1N).<br>•POE (predict, observe, explain): Student predicts the frictional effects of different materials.<br>•On flat surfaces, student investigates static friction with Newton-meter using various materials.<br>•Student compares weight of brick measured with Newton meter (gravitational force) with force required to overcome static friction using various materials between brick and table.<br>•Student sketches experiment and creates chart: material, weight, pull force, and ratio of pull force/normal force (normal force=weight in this case; thus, this ratio is the coefficient of friction). Introduce force diagrams to describe forces.<br>•Ask: what happens to the energy of object slowed by friction? Have students slide wood block back and forth on a floor for a few minutes, then feel the temperature of the block (Ensure safety by choosing responsible students to do experiment). | Newton meters, bricks and various flat materials: sandpaper, aluminium foil, plastic, fabric.<br><br>Science journals |

Jill 24/10/11 8:31 AM
**Comment [18]:** This denies some students who may benefit from hands on experience from gaining that.

| Lesson 3 (Explore): Frictional forces on flat surfaces | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 3. Reflect (7 minutes) | *Formative assessment--frictional forces:*<br>•Student identifies materials with lower/higher coefficient of friction.<br>•Student understands frictional forces slow moving objects; kinetic energy converts to thermal energy.<br>•Process: Student makes predictions with some scientific basis.<br>•Process: Student presents findings in an organised way with a sketch. | |

| Lesson 4 (Explore): Momentum and Impulse. | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (8 minutes) | •Drop basketball with softball directly on top (softball rebounds much higher).<br>•Brainstorm concept of momentum--> a function of an object's mass and velocity. | Basketball and softball. |
| 2. Interact (45 minutes) Small groups | •Create roles (Speaker/Manager/Director) for outdoor student activity: using iPad/iPhone software 'Video Physics', record kicking of ball and process.<br>•Student examines time of impulse and compares with horizontal velocity for 'Standard' kicks (example: http://www.deuce4.net/web/videoPhysics.m4v).<br>•Show baseball video segment and brainstorm other sporting activities involving forces acting over a period of time that result in a change of momentum. | http://www.vernier.com/products/software/video-physics/<br><br>http://www.teachersdomain.org/resource/kqed09.sci.phys.maf.kqedbaseball/ |
| 3. Reflect (7 minutes) | *Formative assessment:*<br>•Student recognises that a force applied over a period of time changes the velocity of an object (Teacher understanding: $F \times t = \Delta mv$). | |

| Lesson 5 (Explain): Design of Playground Slide | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (15 minutes) | Continue with Force Diagrams with direct instruction, examples, and questioning. | |

| Lesson 5 (Explain): Design of Playground Slide | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 2. Interact (30 minutes) Guided design process | •Student designs playground slide for small children to ensure sliding at a slowest possible speed.<br>•Brainstorm design variables (angle), constrain shape to linear slide (ramp).<br>•Provide sample clothing material and plastic material for slide; students wrap block with fabric and calculate coefficient of friction (lesson 3).<br>•Student uses PhET resource to find ideal angle[1].<br>•Student sketches final design in Science Journal with force diagram.<br>[1] Integration: alternatively, this could be math lesson on right angles; answer can be derived graphically. | Plastic strips, fabric swatches, heavy blocks, Newton meter.<br>http://phet.colorado.edu/en/simulation/ramp-forces-and-motion<br>Science Journals |
| 3. Reflect (5 minutes) | *Formative Assessment:*<br>•Student describes directional aspect of gravitational force, frictional force.<br>•Student represents magnitude of force by the relative length of force diagram arrows.<br>•Process: Student composes results clearly and logically. | |

Jill 24/10/11 8:36 AM
**Comment [19]:** This does not really seem to be an Explain lesson – this is where you clarify the terms and ideas your are trying to develop or at least help the students clarify them.

Jill 24/10/11 8:37 AM
**Comment [20]:** I like this idea – slide angle is such an important consideration for young children.

| Lesson 6 (Elaborate): Design of Playground Swing | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (10 minutes) | •Outdoors, select students to see who can do the most swings in 10 seconds (the swing's resonant frequency results in no clear 'winner').<br>•Back in class, open questioning on pendulums. | Playground swing. |
| 2. Interact (40 minutes) | •Design of swing modelled as pendulum.<br>•Question: "How can we change the period?"<br>•Fair test: scaffold "Cows Moo Softly" (Change, Measure, Same) and brainstorm variables (mass, length of string, initial 'push', initial angle of release). | String, weights, measuring tools.<br>Investigative Worksheet (Appendix C) |
| 3. Reflect (10 minutes) | •*Summative Assessment: Investigative Worksheet*<br>•Student plans and implements fair test.<br>•Student concludes correct effect of tested variable.<br>•Student recognises differences and/or similarities between prediction and result.<br>•Student's work uses scientific terminology.<br>•Student's work is neat and presentable. | |

| Lesson 7 (Evaluate): Design of new Playground Equipment | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |

| Lesson 7 (Evaluate): Design of new Playground Equipment | | |
|---|---|---|
| **Objectives** | **Activities and Assessments** | **Resources** |
| 1. Engage (5 minutes) | Announce and discuss design project. | |
| 2. Interact (30 minutes) | •In groups or individually, students sketch and describe design of a new piece of playground equipment that involves movement. Energy, forces, and momentum are identified (where applicable). Explain that the design will be marked, and provide the basis for assessment (below) to students. | |
| 3. Reflect (45 minutes) | Students present design project to class.<br>*Summative Assessment:*<br>• Student demonstrates movement in design.<br>• Student identifies forces that affect movement.<br>• Student evaluates effects of other direct and indirect forces.<br>• Student predicts effects of friction in design.<br>• Student generalises other possible energy transformations in design.<br>• Student reasons with appropriate scientific terms, and backs up claims with evidence.<br>• Design is neatly presented.<br>•Design is safe. | |

RUBRIC FOR SUMMATIVE CONCEPTUAL DESIGN (derived from Skamp, 1998, p. 103-104)
Level 1 Student can describe simple situations involving movement and force using appropriate terminology, such as "push", "pull, "speeding up". Can make sensible observations of a variety of movments using appropriate simple language."
Level 2 Can make observations about movement and force situations and generate interpretations based on patterns, such as "heavy things need more force to move". Uses the language of push and pull, but may harbour varied notions of forces residing in moving objects and has confused ideas about gravity and friction.
Level 3 Can describe a variety of motions in detailed terms and can attempt reasonable explanations of different motions in terms of the actions of forces of different types (gravity, friction, forces due to air, pushes and pulls). Has a basic understanding of gravity. May still harbour a variety of alternate conceptions.
Level 4 Can describe motion in specific terms, such as "speeding up", "slowing down". Can describe the effects of combinations of forces to affect an object's motion in situations where they may oppose or where an object is balnacing under the action of different forces. Can attempt interpretation of complex motions in terms of detailed consideration of different forces.

Jill 24/10/11 8:38 AM
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Jill 24/10/11 8:38 AM
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APPENDIX B: TWLH CHART (for each student)

TWLH Chart (Think, Want, Learn, How) Name:_________________

| **What I *think* I know about movement in the playground** | **What I *want* to know about movement in the playground** |
|---|---|
| in words: | in words: |
| draw a picture: | draw a picture: |
| **What I *learned* about movement in the playground** | ***How* I know it** |
| in words: | in words: |
| draw a picture: | draw a picture: |

APPENDIX C: Investigation Worksheet
(Source: Working Scientifically, Hackling, 2005)

## Planning and Report Worksheet for Science Investigations

Student name ______________________________ Class ______________

Other members of your group ________________________________________

What are you going to investigate?

What do you think will happen? Explain why.

Which variables are you going to:

- change?
- measure?
- keep the same?

How will you make it a fair test?

What equipment will you need?

What happened? Describe your observations and record your results.

Can your results be presented as a graph?

What do your results tell you? Are there any relationships, patterns or trends in your results?

Can you explain the relationships, patterns or trends in your results? Try to use some science ideas to help explain what happened?

What did you find out about the problem you investigated? Was the outcome different from your prediction? Explain.

What difficulties did you experience in doing this investigation?

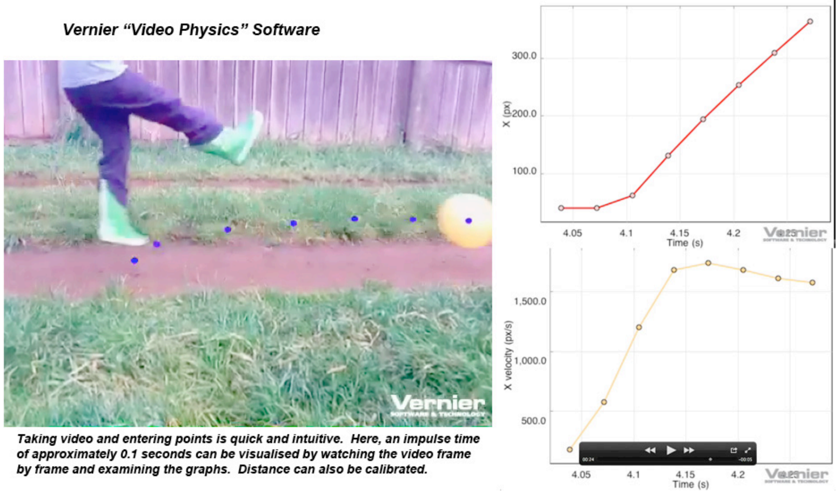
How could you improve this investigation, for example, fairness, accuracy?

Appendix D: ICT resources.

**Lesson 4: Vernier 'Video Physics' Software for iPhone/iPad**
This software is inexpensive ($2.99) and can be used to roughly estimate (more importantly, to visualise) the time of impact. This can help students understand the link between forces, time, and changes in momentum and dispel the alternate conception of force "becoming" part of the motion. The points take seconds to add frame by frame, and the graphs are automatically generated.

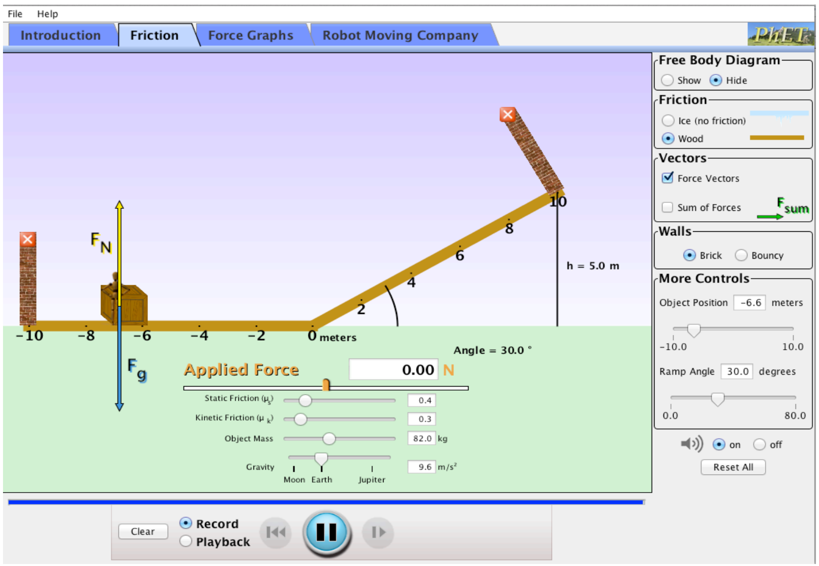
Jill 24/10/11 8:40 AM
**Comment [21]:** excellent

*Vernier "Video Physics" Software*




*Taking video and entering points is quick and intuitive. Here, an impulse time of approximately 0.1 seconds can be visualised by watching the video frame by frame and examining the graphs. Distance can also be calibrated.*

**Lesson 5: Phet Simulation**




Steps: 1. Click "Friction" tab (http://phet.colorado.edu/en/simulation/ramp-forces-and-motion)
2. Set "Static friction" to design value.
3. Use "Object Position" and run/stop button to perform tests.
4. Change "Ramp Angle" to determine minimum.