THE MECHANICAL UNIVERSE AS LISTENING AND SPELLING MATERIAL IN ENGLISH

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INTRODUCTION AND METHOD

THE MECHANICAL UNIVERSE is a video material for use in a high school curriculum in America.[1)]

Among its 16 topics,[2)] NEWTON'S LAWS was chosen as the first listening and spelling material in English for a class of 51 first-year students of Department of Information and Computer Sciences of Kanagawa Univercity at Hiratsuka after discussion with the teaching staff. The decision was unanimous. The content and the basic technical terms it covers are familiar to the science-major students in their native language. Most of the students are 18 or 19 years old, and they are graduates of public high schools. They were not supposed to watch or listen to the dubbed version, since they had learned Newton's laws in a high school curriculum. The major purpose of using this particular video material was to improve their listening and spelling ability in English. The students started listening and transcribing NEWTON'S LAWS in June. The list of technical words and names (Table 3.) was given to the students to use during the summer holidays (8 weeks). All the students finished transcribing the rest of the text by themselves and handed it in at the last class of September, 1989.

The process of improving their listening and spelling ability in English went as follows:

1. In the Language Laboratory the students watched the video while recording the narration on their own tape.

2. The students listened to the tape and wrote down the commentary. At the end of the class they handed in this copy. They were encouraged to use a dictionary.

3. The students took the tape with them so that they could listen to it at home for a week.

4. The teaching staff corrected the dictation with comments and returned it at the beginning of the next class.

5. The video was shown for the second time, and the students continued transcribing the commentary. Most students took notes while watching the video. The video was not shown at the third lesson. The students listened only to the tape.

6. Before the summer holidays a list of words was given to the students so that they could finish transcribing the rest of the text by themselves. There was a great difference in progress at this stage.

7. At the beginning of the new semester the whole text was shown on an OHP, and the students corrected their own transcription with a red pencil, and handed it in.

Table 1. List of Technical Terms Used in NEWTON'S LAWS

	acceleration	**	law
**	action(act)	**	mass
	Aristotle(Aristotelian)	**	mathematics(mathematical)
**	body	*	mechanics(** mechanical)
**	classical mechanics	*	momentum
**	comet	**	motion
*	component		Newton
**	condition		parabola(parabolic)
**	constant	**	physics(physical)
	Descartes	*	planet
**	direction	**	principle
*	dynamics		projectile
*	equation	**	reaction
**	external force	**	resistance
**	falling body	**	rest
**	force	**	science
	Galileo	**	straight line
	gravity		synthesis
**	horizontal(ly)		trajectory
	Huygens	**	universe
*	impetus	*	vacuum
	inertia		vector
	interaction(interact)	*	velocity
	Kepler	**	vertical
	kinematics		

*----at college (first and second years) level
**--at high school level
(by SHOGAKUKAN PROGRESSIVE ENGLISH-JAPANESE DICTIONARY, 2nd edition)

Table 2. Frequency of Occurrence of Technical Words Appearing in the Text

(technical words)	(frequency of occurrence of techinical words appearing in the text)	
acceleration	16	☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆
action	10	☆☆☆☆☆☆☆☆☆☆
Aristotle	1	☆
body	13	☆☆☆☆☆☆☆☆☆☆☆☆☆
classical mechanics	1	☆
comet	1	☆
component	3	☆☆☆
condition	1	☆
constant	6	☆☆☆☆☆☆
Descartes	1	☆
direction	11	☆☆☆☆☆☆☆☆☆☆☆
dynamics	2	☆☆
equation	9	☆☆☆☆☆☆☆☆☆
external force	2	☆☆
falling body	3	☆☆☆
force	21	☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆
Galileo	10	☆☆☆☆☆☆☆☆☆☆
gravity	5	☆☆☆☆☆
horizontal	5	☆☆☆☆☆
Huygens	1	☆
impetus	5	☆☆☆☆☆
inertia	4	☆☆☆☆
interaction	3	☆☆☆
Kepler	1	☆
kinematics	1	☆
law	14	☆☆☆☆☆☆☆☆☆☆☆☆☆☆
mass	8	☆☆☆☆☆☆☆☆
mathematics	2	☆☆
mechanics	2	☆☆
momentum	1	☆
motion	19	☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆
Newton	22	☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆☆
parabola	2	☆☆
physics	2	☆☆
planet	1	☆
principle	4	☆☆☆☆
projectile	10	☆☆☆☆☆☆☆☆☆☆
reaction	2	☆☆
resistance	1	☆
rest	2	☆☆
science	1	☆
straight line	4	☆☆☆☆
synthesis	1	☆
trajectory	4	☆☆☆☆
universe	3	☆☆☆
vacuum	1	☆
vector	4	☆☆☆☆
velocity	3	☆☆☆
vertical	3	☆☆☆

☆ indicates 1 occurrence of each word.

Table 3. The List Given to the Students

Aristotle	Kepler
component	kinematics
dynamics	momentum
Descartes	parabola
Huygens	synthesis
impetus	trajectory

The above words appeared in the latter half of the text which most of the students transcribed during the holidays. Because of this a higher proportion of the students was able to identify these names and technical terms.

RESULTS

The results shown in tables 4 and 5 concern the correct identification of words by the first-year students. The words are from the text NEWTON'S LAWS. The table 4 shows the students' difficulty in identifying them in the English context, and table 5 in spelling them correctly.

Table 4. Percentage of Students Identifying Word at First and Final Listening

(technical words)	(first	- final)
acceleration	53%	→ 100%
action	55%	→ 100%
Aristotle	70%	
body	7%	→ 87%
classical mechanics	60%	
comet	72%	
component	67%	→ 77%
condition	73%	
constant	7%	→ 76%
Descartes	73%	
direction	73%	→ 93%
dynamics	90%	→ 90%
equation	50%	→ 97%
external force	34%	→ 62%
falling body	21%	→ 40%
force	100%	→ 100%
Galileo	31%	→ 96%
gravity	33%	→ 69%
horizontal	27%	→ 55%
Huygens	67%	
impetus	47%	→ 50%
inertia	10%	→ 48%
interaction	34%	→ 59%
Kepler	90%	
kinematics	55%	
law	33%	→ 83%
mass	87%	→ 93%
mathematics	57%	→ 90%
mechanics	57%	→ 73%
momentum	77%	
motion	87%	→ 97%
Newton	40%	→ 93%
parabola	37%	→ 77%
physics	62%	→ 70%
planet	83%	
principle	7%	→ 66%
projectile	7%	→ 76%
reaction	50%	→ 72%
resistance	30%	
rest	23%	→ 67%
science	87%	
straight line	24%	→ 83%
synthesis	53%	
trajectory	24%	→ 63%
universe	67%	→ 93%
vacuum	3%	
vector	50%	→ 97%
velocity	33%	→ 90%
vertical	33%	→ 67%

■ indicates that "at first listening" 5% of the students identified word.
□ indicates that "at final listening" 5% of the students identified word.

Table 5. Percentage of Students Correctly Spelling Word at First and Final Listening

(technical words)	(first	- final)
acceleration	43%	→ 68%
action	55%	→ 100%
Aristotle	60%	
body	7%	→ 87%
classical mechanics	43%	
comet	72%	
component	67%	→ 77%
condition	73%	
constant	7%	→ 76%
Descartes	60%	
direction	67%	→ 86%
dynamics	90%	→ 90%
equation	50%	→ 97%
external force	34%	→ 62%
falling body	21%	→ 40%
force	100%	→ 100%
Galileo	31%	→ 92%
gravity	33%	→ 69%
horizontal	27%	→ 55%
Huygens	13%	
impetus	47%	→ 50%
inertia	10%	→ 48%
interaction	34%	→ 59%
Kepler	87%	
kinematics	53%	
law	33%	→ 83%
mass	87%	→ 93%
mathematics	57%	→ 90%
mechanics	53%	→ 60%
momentum	37%	
motion	87%	→ 97%
Newton	37%	→ 93%
parabola	37%	→ 77%
physics	62%	→ 70%
planet	83%	
principle	7%	→ 66%
projectile	7%	→ 76%
reaction	50%	→ 72%
resistance	30%	
rest	23%	→ 67%
science	83%	
straight line	24%	→ 83%
synthesis	53%	
trajectory	24%	→ 63%
universe	53%	→ 89%
vacuum	3%	
vector	40%	→ 97%
velocity	30%	→ 90%
vertical	33%	→ 67%

(Scale: 0% — 25% — 50% — 75% — 100%)

■ indicates that "at first listening" 5% of the students correctly spelled word.

□ indicates that "at final listening" 5% of the students correctly spelled word.

DISCUSSION

For most students, training in a language laboratory was a new experience. The video, CURVED SPACE AND BLACK HOLES, was used in a similar way during the second term. Some of the students remarked that it 'seemed' easier than NEWTON'S LAWS. The technical terms and sentence patterns in CURVED SPACE AND BLACK HOLES are much the same as those in NEWTON'S LAWS.

In the questionnaire at the end of the academic year, 48 out of 51 students wrote that the concept of the material was easy to understand since they had learned it in high school. Three students thought the tape (18 minutes) was too long. However, they enjoyed it, presumably because the videos are produced in the way to attract students and the material is related to their major.

From the viewpoint of motivating students to improve their listening and spelling ability in English, it is well known that language laboratory education can be helpful and effective. This application of language laboratory techniques in the science area shows that teaching of English can also be furthered using materials such as the video THE MECHANICAL UNIVERSE. For students primarily interested in science, such videos are an ideal way of learning English. Furthermore, the use of the language laboratory, and its technology, proved in itself to be a source of motivation to learn English.

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Notes:

1) "This material has been accepted from the college television course, THE MECHANICAL UNIVERSE, and re-edited specifically for use in a high school curriculum. THE MECHANICAL UNIVERSE is founded by the Annenberg/CPB Project made possible by grant from the National Science Foundation." The Annenberg/CPB Project, California Institute of Technology, 1985. Maruzen Corporation Ltd. imported it and produced a dubbed version in 1988.

2) THE MECHANICAL UNIVERSE

1. NEWTON'S LAWS
2. THE APPLE AND THE MOON
3. HARMONIC MOTION
4. NAVIGATING IN SPACE
5. CONSERVATION OF ENERGY
6. CONSERVATION OF MOMENTUM
7. ANGULAR MOMENTUM
8. THE FUNDAMENTAL FORCES
9. THE LAW OF FALLING BODIES
10. INERTIAS
11. THE MILLIKAN EXPERIMENT
12. MOVING IN CIRCLES
13. KEPLER'S LAWS
14. INTRODUCTION TO WAVES
15. TEMPERATURE AND GAS LAW
16. CURVED SPACE AND BLACK HOLES

Appendix

NEWTON'S LAWS

Force equals mass times acceleration. Mechanics, the science of motion, can be summarized in that one equation, F= ma. It is the heart of classical mechanics. When trying to describe the basic machinery of the world, a natural question is where to begin. Isaac Newton began with three fundamental principles -- Newton's Laws. And with the incredible speed and elegance of unleashed genius he explained the motion of almost everything on and above the surface of the earth.

Refined to their essence, Newton's three laws are one profoundly powerful equation. Force equals mass times acceleration. Understand that equation, what it means and how to use it, and in the end, it's possible to understand the mechanical universe.

At the same time, understand that considerable complexity can reside in what appears to be pure and simple. For example, a closer look at F= ma immediately reveals two complications.

First, F= ma is a vector equation. Both force and acceleration are vectors. In other words, they have definite directions. In F= ma they must have the same direction.

The second complication arises in the symbol 'a' for acceleration. Remember acceleration isn't a position of something. And it's not how fast something changes its position. Acceleration is how fast something changes its velocity.

When a body or mass falls, gravity exerts a force, 'F'. Force in the downward direction, of course. And the result is acceleration.

So there it is. F= ma. Acceleration and force in the same direction--complicated yet beautiful in its simplicity. That's the well known equation.

And in the case of a falling body, what's known about acceleration? It's constant, for one thing. And for another, it's the same for all falling bodies in the idealized conditions of vacuum. And what's more, it's called 'g'.

The force of the earth's gravity on every falling body equals its mass times the acceleration 'g' in the downward direction. This force is the body's weight.

But this equation also describes motion for other than the downward direction. Gravity exerts the same force on a body, no matter which direction that body travels.

Once a falling object's in motion aside from air resistance, gravity is the only force acting on it. Whether dropped from a tower, shot from a towering mountain, or heaved by a towering mountain of a man, all moving objects fall under the influence of gravity.

An equation that explains the path of any projectile on earth--it's powerful indeed. And to see how it really works--it's necessary to go back to the beginning.

With his first law, Newton embraced the idea of inertia. He wrote--every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it. Inertia was an idea that Newton inherited from Galileo. It was an extraordinary idea that if illustrated with modern images goes something along these lines. Once a body is in motion, it naturally continues in a straight line unless influenced by some force.

Newton's second law indicates exactly how force changes the motion of an object. As Newton himself explained it, the change in motion is proportional to the force impressed, and it is made in the direction of the straight line in which the force is impressed. Newton used the word motion to mean momentum, the velocity of the body multiplied by its mass.

To every action there is always an equal reaction, or, the mutual actions of two bodies upon each other are always equally directed to contrary parts. Something cannot touch something else without being touched in return. In other words, bodies don't merely act. They interact with one another.

At he same time all three of Newton's laws act and interact throughout the physical world. And the trajectory of any projectile in a powerfully moving fashion demonstrates the consequences of Newton's three laws. When an object is launched, and allowed to travel freely, what's the nature of its trajectory? No matter what the projectile and its purpose, could it be that all trajectories are essentially the same?

Understanding the course of any projectile arises from an insight into the laws that govern force in motion. The path of any projectile can be described in the field of mathematics.

In Newton's own words, "Then from these forces I deduce the motions of the planets, the comets, the moon, and the sea."

Newton wasn't the first to ponder the path of a flying object on earth, or that of one in the heavens. But he stood alone in his knowledge that the same laws govern the course of both.

Still, long before Newton, Galileo Galilei described projectile motion perfectly. He realized bodies can fall vertically and move horizontally at the same time. From Galileo's point of view, which took in everything from the heavens to the heavenly gardens of the Renaissance, the body's motions has two components completely independent of each other.

Galileo's extraordinary vision is explained by Isaac Newton's extraordinary equation. The vertical component of the vector force is 'mg' downward, or '-mg'. No force at all acts in the horizontal direction. Only the vertical component of acceleration is '-g'. In the horizontal direction, where there is no force, the acceleration is zero. Acceleration is the rate of change of velocity. Since the horizontal speed is not changing, it must be constant. Constant speed in the horizontal direction and constant acceleration downward, both acting independently and simultaneously. These are the elements of Galileo's trajectories, and they're also the results of Newton's equation--force equals mass times acceleration, F= ma.

But to understand the ongoing significance of F= ma, it is necessary to return to a time before scholars had its help in grappling with worldly phenomena.

To explain the unescorted motion of projectiles, such as spears, arrows, and cannonballs, scholars came up with the idea of impetus. Launching a projectile, imbued it with a finite amount of impetus which gave the object its motion. When its impetus was consumed, the object suddenly dropped to earth.

Impetus wasn't a bad idea. But, it fell short of its target. The medieval idea of impetus fell just short of the principle of inertia which wasn't hit upon until the Renaissance when the parabolic path of a real projectile was discovered by Galileo.

In Galileo's words, "It has been observed that missiles and projectiles describe a curved path of some sort, however, no one has pointed out the fact that this path is a parabola." With such insight, Galileo was living to see the two thousand year reign of the Aristotelian world view come to an end. And he wasn't alone. About the same time, Johannes Kepler, Christian Huygens in the Netherlands and Rene Descartes in France, and others, also began to see the universe with new eyes.

As extraordinary as this collection of scientists was, their individual viewpoints overlooked something--a synthesis, an organizing principle of the physical world as a whole.

It would take extraordinary circumstances to explain the world. It would require the right person, in the right place at the right time. The right time was 1665. And the right person was Isaac Newton.

At only 23 years of age, Newton conceived the discoveries that would alter forever the world's understanding of the universe. With just three fundamental laws, Newton gave motion a cause and in doing so, his dynamic principle completed Galileo's mathematical description of motion. In other words, by Galileo's kinematics described motion, Newton's dynamics explained it.

Newton's first law is a statement of the law of inertia. Every body continues in a state of rest, or of motion, along a straight line with a constant speed, unless an external force acts on it.

Newton's second law, $F = ma$, states that the vector sum of the external forces acting on a body of constant mass is equal to the object's mass times its acceleration.

Newton's third law is a law of interaction. For every action there is always an equal but opposite reaction.

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