''KIT PHYSICS NAVIGATION'' SHOWING RELATIONSHIP BETWEEN HIGH SCHOOL AND UNIVERSITY

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ABSTRACT

CDIO Syllabus and CDIO Standard suggest that engineering students should acquire fundamental scientific knowledge as the basis of CDIO in order to be able to apply it to disciplinary knowledge and should understand the connections between them. We have been developing an e-learning website of physics visualizing the connections between fundamental and advanced knowledge by using graph drawing. Also we have been developing a self-adaptive e-learning environment that learners can efficiently acquire integrated knowledge by connecting high school and university learning smoothly with hyperlinks on each webpage.

KEYWORDS

Scientific Knowledge, STEM, Self-Adaptive, E-Learning, Standards: 7, 8, 10,

INTRODUCTION

The CDIO (Conceive, Design, Implement, Operate) initiative advocates that the engineering students should try to foster the fundamental knowledge of mathematics, science, etc., as well as basic expertise. In Standards 7, it is suggested ''with integrated learning experiences, faculty can be more effective in helping students apply disciplinary knowledge.'' And in Standards 8 it is suggested ''instructors can help students make connections among key concepts and facilitate the application of this knowledge to new settings.''

For example, if students have only the fragmental knowledge and cannot find the way to relate it with each other, it is difficult for them to solve the problems they found and to spark the idea. In order to be innovative, students should understand the relationship between the knowledge comprehensively and should learn how to relate them. Also they need to acquire knowledge of a wide range of areas, such as the mathematics, physics, engineering, etc. However, there is no self-adaptive e-learning website for STEM (Science, Technology, Engineering, Mathematics) which enables students to understand the relationship between the fragmentary knowledge. These days it's often the case that the students do an internet search by using a smartphone with the spread of it to find the answers for the problems they couldn't solve. Self-adaptive e-leaning website optimized for each student's knowledge will be of great help for them to acquire integrated knowledge and understand the relationship between the fragmentary knowledge by clicking hyperlinks on each webpage. Such a website should be designed to navigate students from a webpage which contains difficult concept to much easier concept with hyperlinks. Also, it should contain the knowledge structure of high school and university learning so as to provide students with comprehensive knowledge.

In CDIO Syllabus, it is indicated ‘‘the development of a deep working knowledge of technical fundamentals is, and should, be the primary objective of undergraduate engineering education.’’, and ‘‘Modern engineering professions often rely on a necessary core Knowledge of Underlying Sciences’’ (Crawley, 2001). Figure.1 shows Building blocks of knowledge, skills, and attitudes necessary to CDIO Systems (Crawley, 2001). Figure.2 shows Hierarchy of Technical Knowledge and Reasoning (Crawley, 2001). These figures show that Scientific Knowledge is the basis of all knowledge in CDIO Systems.

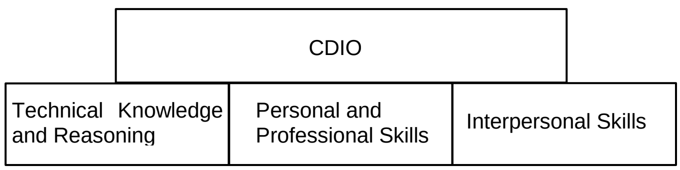


Figure 1: Building blocks of knowledge, skills, and attitudes necessary to CDIO Systems

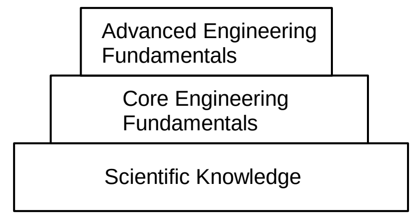


Figure2: Hierarchy of Technical Knowledge and Reasoning

Various e-learning website have been developed (Negash et al., 2001). E-learning was a powerful instructional teaching and learning process (June & Leong, 2006), and a blended learning using e-learning was reported in connection with CDIO (Nyborg & Christiansen, 2016). Kanazawa Institute of Technology (KIT) published the self-adaptive e-learning website of mathematics, KIT Mathematics Navigation on the web in 2004. And the website stores over two thousand pages now. Recent KIT Mathematics Navigation has been developed in association with learning materials by combining print materials with web based training (Nakamura, 2011), graph drawing of knowledge structure of mathematics (Nakamura, 2014; Nakamura, 2015), and self-adaptive e-learning website of mathematics (Nakamura, 2016).
For the purpose of enriching the STEM e-learning environment based on the CDIO initiative, we published a self-adaptive e-learning website of physics, KIT Physics Navigation on the web in March 2016 (Nakamura et al., 2016) and developed a visualizing system of knowledge structure based on STEM e-Learning website (Nakamura et al., 2018). Multilingual translation is possible in Google translation. One of our concepts is to describe the connection between high school and university learning for the students to understand the relationship between the fragmentary knowledge smoothly. It is currently at issue that the university students have feelings of being not good at physics. As one of the reasons for this, it is mentioned that, there is a certain level gap of the knowledge among high school and university learning. For example, the differential and integral calculus is not used in the physics class of high school in Japan. It is needed to fill in the gap by connecting high school and university learning smoothly.
Here we report the details of self-adaptive e-learning website, KIT Physics Navigation. Firstly, we will explain characteristics of KIT Physics Navigation. Secondly, we will explain the connections between high school and university learning, and the meaning of visualising the connections with hyperlinks. Finally, we will summarize briefly.

KIT PHYSICS NAVIGATION

Characteristics

KIT Physics Navigation has following characteristics:

・Website was built on the concept that one webpage contains one knowledge. On the webpage, mathematical expressions and figures are compactly arranged and it is easy to see by using smart phone as well as personal computer.

・Website provides learners with e-learning environment which enables them to understand the connection between high school and university learning smoothly.

・Self-adaptive e-learning website which helps learners to deepen their knowledge of physics with accessing any webpages regardless of their knowledge amount.

・ Website connects the knowledge of physics in high school and university learning with hyperlinks.

・ Website succeeded in visualizing the connections between advanced knowledge and fundamental knowledge of physics with Graph drawing .

・Website provides ICT teaching materials to promote learners' better understanding toward the motion of an object by using simulation.

・Multilingual translation is possible by using Google Translate.

Connection Between High School and University Learning in Physics

Here, we explain connection between high school and university learning in physics. Recently, we have almost finished making webpages about dynamics in high school learning, and now we are making webpages about electromagnetics in high school learning and webpages about dynamics in university learning. In Japanese high school, there are two types of physics textbooks. One is Basic Physics and another is Applied Physics. Figures 3 and 4 show the tables of contents of dynamics in Basic and Applied Physics, respectively. Figure 5 shows the hyperlink structure visualizing the connections between advanced and fundamental knowledge.

Basic Physics

Part 1 Motion of Objects and Energy

Chapter 1 Motion of Objects

Position, Displacement, Distance, x–t graph, Velocity, v–t graph, Composite velocity, Relative velocity, Acceleration, a–t graph, Linear uniform motion, Linear motion of uniform acceleration, Equation of linear motion of uniform acceleration (derivation from graph), Equation of linear motion of uniform acceleration (derivation from integral), Free fall, Throwing straight down, Throwing straight up , Horizontal projection, Oblique throw

Chapter 2 Law of Motion and Various forces

Force, Composition and decomposition of force, Force balance, Newton's law of motion , Newton's first law of motion (law of inertia), Newton's second law of motion (low of motion), Newton's third law of motion (low of action and reaction), Difference between Force balance and low of action and reaction, How to make equation of motion, Gravity, Normal reaction, Static frictional force, Kinetic frictional, Air resistance, Hooke's law, Pressure, Water pressure, Buoyancy

Chapter 3 Work and Mechanical Energy

Work, Power, Principle of work, Gravitational potential energy, Kinetic energy, Elastic potential energy, Conservation law of mechanical energy

Figure 3: Dynamics in Basic Physics

Applied Physics

Part 1 Force and Motion

Chapter 1 Rigid body

Pisition of center of gravity, Center of gravity for two mass point system (one demension), Center of gravity for two mass point system (two demensions), Center of gravity for n mass point system (two demensions), Center of gravity for n mass point system (two demensions)(different solution), Center of gravity for two mass point system (three demensions), Center of gravity of rigid body (two dimensions), Moment of force, Equilibrium condition of rigid body (one dimension), Equilibrium condition of rigid body (two dimensions), couple of forces

Chapter 2 Motion in a plane and parabolic motion

Velocity of motion in a plane, Relative velocity of motion in a plane , Acceleration of motion in a plane, Free fall, Throwing straight down, Throwing straight up , Horizontal projection, Oblique throw

Chapter 3 momentum

Impulse, Impulsive force, Momentum, Impulse and momentum, Internal force and external force, Momentum conservation law, Coefficient of restitution

Chapter 4 Circular motion and universal gravitation

Uniform circular motion, Inertial force, Simple harmonic motion, Law of universal gravitation, Kepler's law

Figure 4: Dynamics in Applied Physics

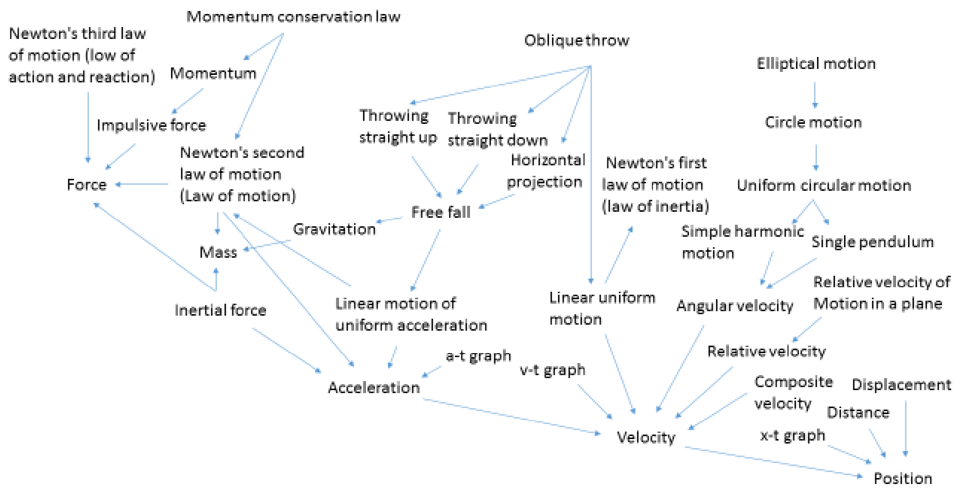


Figure 5: Hyperlink structure

Figure 6 shows graph drawing of the hyperlink structure. Here, a red node indicates the webpage learners are browsing. Green nodes indicate the knowledge of physics which is connected to the webpage learners browsed, and cyan nodes indicate knowledge of mathematics. Connections among key concepts in Standards 8 are visualized by directed edges with the directions from advanced knowledge to fundamental knowledge. We are developing a self-adaptive e-learning website that helps learners to deepen their knowledge with accessing any webpages by clicking the hyperlinks, and helps to understand the connections among knowledge. As suggested in CDIO Syllabus, ‘‘Modern engineering professions often rely on a necessary core Knowledge of Underlying Sciences’’, we will cover all of core STEM Knowledge in KIT Navigations in the future.

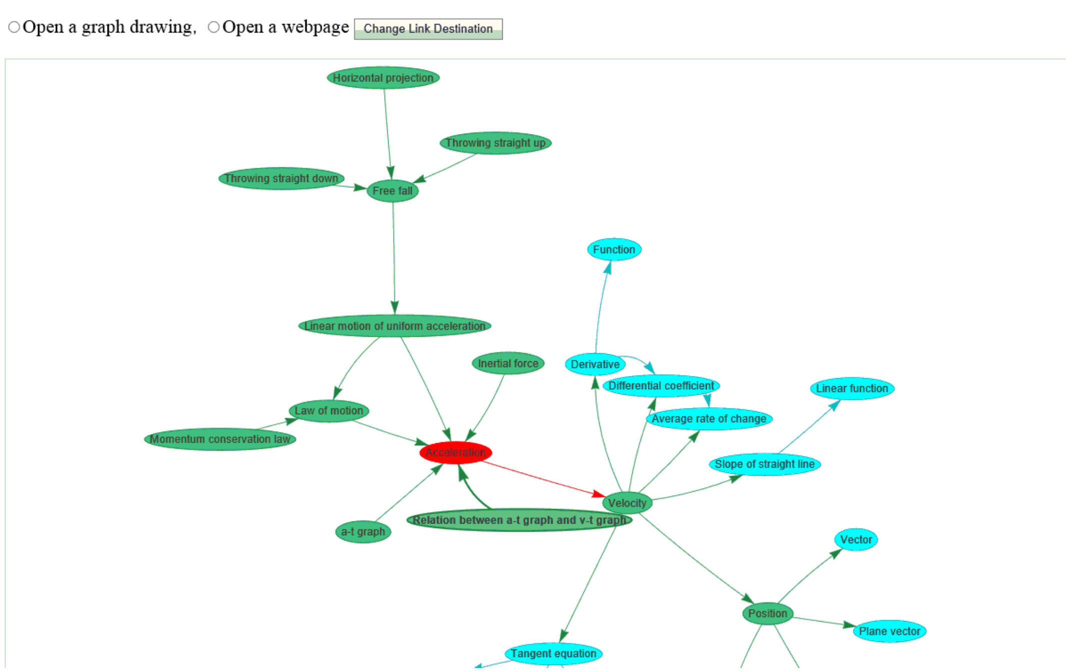


Figure 6: Graph Drawing

A few years ago, after the lecture of physics in university, a student came to one of the authors and said, ``I do not understand the meaning of calculus.'' For him, the author explained its meaning by using figs. 7 to 9 as follows. An equation of position for linear motion of uniform acceleration is derived by calculating the area of a trapezoid in v-t graph in high school in fig. 8 and is also derived by integrating an equation of velocity in university in fig. 9. Here, initial condition is given. On the contrary, the equation of velocity is obtained by calculating the slop of a tangent line in x- t graph in high school and is obtained by differentiating the equation of position in university.

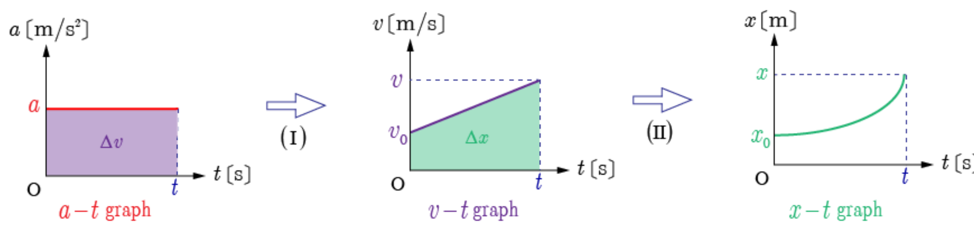
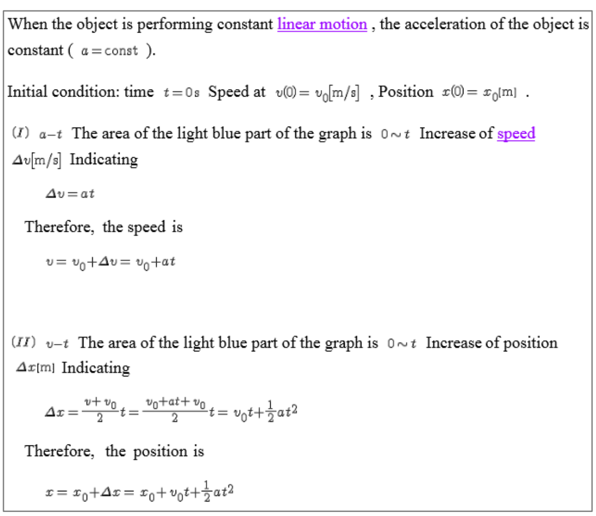


Figure 7: a-t, v-t, x-t graphs for linear motion of uniform acceleration



When the object is performing constant linear motion , the acceleration of the object is constant ($a = \text{const}$).

Initial condition: time $t = 0\,\text{s}$ Speed at $v(0) = v_0[\text{m/s}]$, Position $x(0) = x_0[\text{m}]$.

(I) $a-t$ The area of the light blue part of the graph is $0 \sim t$ Increase of speed $\Delta v[\text{m/s}]$ Indicating

$$\Delta v = at$$

Therefore, the speed is

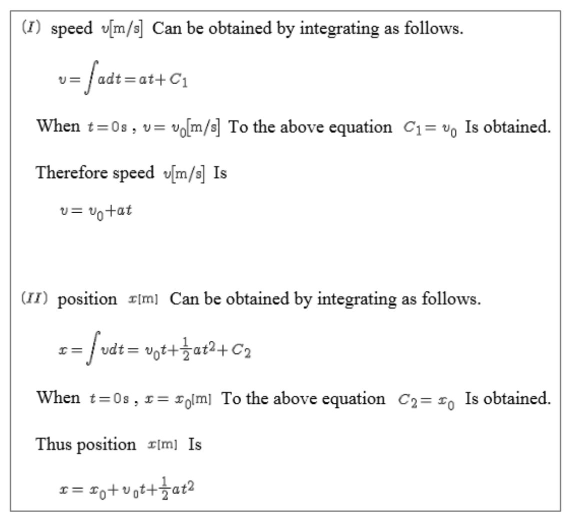
$$v = v_0 + \Delta v = v_0 + at$$

(II) $v-t$ The area of the light blue part of the graph is $0 \sim t$ Increase of position $\Delta x[\text{m}]$ Indicating

$$\Delta x = \frac{v+v_0}{2}t = \frac{v_0+at+v_0}{2}t = v_0 t + \frac{1}{2}at^2$$

Therefore, the position is

$$x = x_0 + \Delta x = x_0 + v_0 t + \frac{1}{2}at^2$$



(I) speed $v[\text{m/s}]$ Can be obtained by integrating as follows.

$$v = \int a dt = at + C_1$$

When $t = 0\,\text{s}$, $v = v_0[\text{m/s}]$ To the above equation $C_1 = v_0$ Is obtained.

Therefore speed $v[\text{m/s}]$ Is

$$v = v_0 + at$$

(II) position $x[\text{m}]$ Can be obtained by integrating as follows.

$$x = \int v dt = v_0 t + \frac{1}{2}at^2 + C_2$$

When $t = 0\,\text{s}$, $x = x_0[\text{m}]$ To the above equation $C_2 = x_0$ Is obtained.

Thus position $x[\text{m}]$ Is

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

Figure 8: A derivation in high school

Figure 9: A derivation in university

After the explanation, the student told the author ``for the first time, I understood the meaning of calculus.'' At that time, the author thought that it is very significant for students to clarify the connection between high school and university concepts. There is a certain gap between high school and university concepts. If we can fill such a gap by connecting knowledge in high school and university learning with hyperlinks and graph drawings, then it will help learners to have essential understanding, not just memorizing a piece of knowledge. Furthermore, learners will be able to derive a fundamental equation easily by understanding a definition on the website. Such a learning method leads learners to turn their bad feelings for physics into good one. Thus we visualized the connections between high school and university concepts with hyperlinks. It is very important that instructors teach the connections among key concepts clearly in lecture as is pointed out in Standard 8. The website which emphasizing the connections between high school and university concept with graph drawings is very useful for both of students and instructors, and it will also make a contribution to improve teaching skills of instructors in Standard 10.

SUMMARY

As pointed out in CDIO Syllabus and CDIO Standard, it is essential for engineers to learn fundamental scientific knowledge as the basis of CDIO and to understand how to connect pieces of fragmental knowledge they have with each other. We have been developing the self-adaptive e-learning website which enables learners to connect advanced knowledge to fundamental knowledge as well as that of high school and university learning with accessing any webpages. In graph drawings, nodes indicate a piece of knowledge, and directed edges indicate the connections between advanced and fundamental knowledge. Our website enables engineering students to acquire fundamental knowledge as the basis of CDIO and understand the connections between them efficiently.

As a future assignment, we are considering to develop another self-adaptive e-learning website in field of electromagnetics, wave mechanics, optics, heat mechanics, etc., to enhance the STEM environment. Furthermore, we will confirm the efficacy of KIT physics navigation to the students.

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BIOGRAPHICAL INFORMATION

Tomoshige Kudo is an Assistant Professor in Academic Foundations Programs at Kanazawa Institute of Technology. His current research focuses on Peer Instruction lecture in mathematics and physics. He develops self-adaptive e-learning website, ''KIT Physics Navigation'', and researches foundation of quantum mechanics.

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