Why the ‘Internet of Learning Things’ is key to modernising education
Almost 300 million 15 to 24 year olds globally are not working or studying, and this problem is most acute in Asia. Yet at the same time Asian employers have difficulty in finding people with the right kind of skills, with Asian IT companies facing the highest levels of skills shortage anywhere in the world.

This paper aims to help education decision makers and teachers in Asia understand what is happening in the world of technology, what new skills are needed, and how the Internet of Things (IoT) can be used to improve skills and make learning and schools more effective.

In the last 50 years, we have witnessed a technology driven revolution equal in magnitude to the transition from the Middle Ages to the modern world. However, the most profound shift in the evolution of technology yet has only just begun - the merging of the physical and virtual worlds into the Internet of Things.

The Personal Computer and the ‘Internet of People' defined the previous technological era. Embedded computing, sensors and ubiquitous technologies will define the ‘Internet of Things' era.

**The Internet of Things (IoT): Getting a Deeper Insight**

‘Things', in the IoT world, can refer to a wide variety of physical objects such as sensors, motors, and valves. To help explain how IoT works, we can call these things ‘machines'. Some machines collect data, and other machines use this data to control other machines.

In essence, the IoT can be thought of as machines connected together over the Internet. When machines, such as a sensor, embedded computer and motor are connected, this scenario is known as “Machine to Machine” (M2M) communication. An Internet of Things scenario occurs where multiple M2M scenarios are connected over the Internet.

**Business Usage Scenarios**

So far, the IoT has been most visible in the industrial and logistic landscape such as:

- Tracking objects
- Monitoring sensitive equipments
- Point-of-sale purchases
- Inventory management
- Identification

**Consumer Usage Scenarios**

Typical consumer usage examples of IoT include:

- Smart thermostat systems
- Washer/dryers that utilize Wi-Fi for remote monitoring

According to Oxford University, 47% of today's jobs could be automated in the next two decades. The Internet of Things will fuel this wave of automation.
THE IOT OPPORTUNITY FOR EDUCATION

IoT technologies are already being used in informal learning environments - for example, museums are increasingly using augmented reality. With devices increasingly able to talk with other devices, augmented reality can turn everyday features in a student’s environment into learning objects. For example, with the power of IoT students can use their phone to:

• Access the historical significance of a building
• Get key scientific facts of plants or animals
• Control a drone and receive live images

Understanding the IoT Advantage for Education

In the UK, a $1.2m scheme has been established to find out how IoT can enhance learning in Science, Technology, and Geography in schools. Students and teachers are being taught to measure and share data using new IoT technologies in ways that help make learning fun, and linked directly to the curriculum.

More generally, IoT technologies are appearing in schools due to increased STEM, Computer Science, Design and Making activities.

Creating New Learning Possibilities with IoT

Students need to develop what Howard Gardener calls the “synthesizing mind”, the result of which is to be able to develop better ways of doing things. IoT technologies can enable this in three main areas – Programming or ‘Coding’, Science, and Making.

1. PROGRAMMING

Teachers are increasingly seeing programming as a new form of literacy – a language for students to convey their ideas, develop computational thinking, and solve problems.

Simplifying the Path to IoT Solutions Development

To most people, programming seems difficult, and only for the more able and mathematically orientated learners. However, new tools – such as Scratch* - are making it easy for children of all ages and abilities to learn how to program.

Once students have learned how to program in Scratch, they can move on to Arduino*, which takes computing into the physical world. Using Arduino, students can easily build, program and control simple IoT solutions from components such as sensors, switches, displays, communications modules, motor controllers, and much more.

IoT Idea - Programming

Galileo 'blink'.
This simple code is the starting point for learning to control physical events with a computer. From here, it's a short step to controlling motors with code – a central tenet of Robotics.

```c
void setup()
{
  pinMode(13, OUTPUT);
}

void loop()
{
  digitalWrite(13, HIGH);
  delay(1000);
  digitalWrite(13, LOW);
  delay(1000);
}
```
2. SCIENCE

IoT offers a rich set of tools to help students learn Science. A few examples of how IoT technologies can be used in Science include:

- Observing nature and sending images for analysis
- Using development boards to teach Electronics
- Delivering a more engaging learning experience for complex concepts like resistance, capacitance, transistors

![Figure 1. The Intel® Galileo Development Board can be used with a range of sensors in Science](image)

**Bringing a New Dimension to Learning**

Whilst data logging – the use of instruments to capture and view data – is well established in Science education, IoT offers a new, more effective and engaging way to learn Science.

Now, not only can learners capture and analyse data, they can make that data do something – e.g. trigger a reaction when a given threshold is reached.

![Figure 2. Children at Cadoxton Primary School, Wales, UK build a Robot Buggy with an ultrasonic sensor.](image)

**The Power of IoT in Education can be seen in the example scenarios below:**

Monitoring moisture levels around plants & automatically watering the plants when levels become too low.

An Aquaponics system that constantly monitors and analyzes the conditions of fish and plants, and takes automated corrective actions to balance environmental factors based on data from sensors and the Internet.

The aquaponics system gives a complete overview of factors such as temperature, pH, soil moisture, O2 content etc. Learners can control variables with heaters, lights and fish feeders remotely using a mobile phone app. Collected data can be analysed to get insights into physical, chemical and biological processes.

**IoT Idea – Science**

**Weather Station**

A weather station in a school offers a lot of learning potential. But imagine hundreds of weather stations across many schools contributing data to an IoT website that enables students analyze and question data across a wide geographic area.
"Lately, the maker movement has attracted the attention of educators, as a way of getting youngsters interested in STEM subjects".

Closely aligned to the Internet of Things revolution is the Maker Movement, accelerated by falling costs of desktop manufacturing tools such as 3D printers and laser cutters. Small companies, or even individuals, can now make objects that were previously only viable through well-funded R&D programs.

**3D Printers – Redefining Digital Making**

3D printers are a key driving force in this new 'Digital Making' world, and many are finding their way into schools, opening up great learning opportunities like:

- Providing a 'Science and Maths lesson in a box' – e.g. polymer chemistry, thermodynamics, and the geometry behind positioning the printer nozzle
- Teaching Mathematical 'Topology' concepts by building 3D shapes from geometric formulae
- Making models of molecules, eyeballs, cells and sine waves

**Taking 3D Printing to the Next Level**

The Intel® Galileo Development Board can power 3D printers, but it's the combination of 3D printed parts with Intel's Edison that is particularly exciting, which throw up incredible possibilities like:

- Giant Hexapods that can see through an iPad*
- Dresses that protect the wearer's personal space

**Wearables Technology – Driving the Future of Learning**

Wearables offer a particularly rich area for learning and a great way to combine design, electronics and programming. For example, wearables can be used to:

- Customise school backpacks to display graphics and words
- Offer an ever-expanding creative canvas for learning
Robotics – The New Standard for Digital Making

Robotics is another rich area for digital making, and combines disciplines across the STEM spectrum. Take, for example, the ‘Data Monster’ - a wooden robotic arm with sensors controlled by an Intel® Galileo board, which moves if you wave your hand close to it. This can be connected to the Internet and programmed to make “excited” movements when it detects a specific post on Twitter*.

Driving a More Intelligent Way of Learning

There is a rapidly growing realisation that students learn more from creating technology than just consuming it. Harvard’s “Project Zero” suggests there is a need to develop the “capacity to shape one’s world through building, tinkering, designing, or hacking”.

IoT technologies offer completely new kinds of learning experiences and will enable children to “read the physical world” they live in.

Engaging Students in Interactive, Collaborative Learning

IoT and mobile technologies open up opportunities for deeper and much more personalised and collaborative models of learning. IoT technologies can create new and innovative ways of learning like project- and enquiry-based learning that can:

- Help students learn through all their senses, and stretch their curiosity
- Open the door to a vast spectrum of Project Based Learning (PBL) opportunities
- Heighten students interest and activate their information-seeking behavior, for deeper processing of information and resulting in better performance

“Kids learn through all their senses and they like to touch and manipulate things”.

- Ben Mardell, PhD, Researcher with Project Zero, Harvard* University

Promoting Gender Equality in Technology

Whilst STEM subjects tend to be preferred by boys, IoT technologies open doors to rich learning opportunities to both girls and boys alike, for example:

- Companies, such as Cutecircuit*, offer inspiration to girls and boys wishing to express themselves creatively through fashion and technology
- IoT technologies offer multiple entry points to engage more girls & women in Computer Science & Engineering
- Recent research by Intel found that girls who make, design, and create things with electronic tools develop stronger interest and skills in Computer Science and Engineering

IoT: ACCELERATING EDUCATION TRANSFORMATION

IoT Idea - Making

‘Hack-Pack’

Most students have a backpack, and what better creative canvas for them to express themselves digitally? Development boards – like Intel® Galileo and Edison – enable students to program displays and control them with their phones.

IoT Idea - Wearables

Reinvent the T-shirt

A simple, yet highly effective project for developing IoT skills for turning the humble t-shirt into an electronic canvas.
Enhancing the Classroom Experience

In a recent pilot study by the University of Salford and architects, Nightingale Associates*, it was found that the classroom environment can affect a child’s academic progress over a year by as much as 25%.

IoT technologies can be used to improve learning conditions and environments, for example:

- The Intel IoT SmartEDU project uses sensors & data to control lighting and temperature levels so they are optimal for learning.
- Carbon Dioxide sensors linked to embedded computers & control technology can improve learning, as air quality in classrooms have a significant effect on learning performance.

Enabling a Safe & Healthy Learning Environment

Education institutions need to ensure the well-being of their students. Their safety, health and happiness all contribute to their success, and IoT can play a significant role in this.

A few examples of how IoT can enable a safe and healthy learning experience are:

- The implementation of IoT based security technologies have made students feels more secure and less likely to skip class.
- Wearables can help students to receive and show rewards, engage with learning apps, track their progress, and receive notifications.
- Parents can take advantage of cashless payment and location-aware systems to keep track of their children.

In the U.K. a study based on data from accelerometers given to 7-year-olds found that half were sedentary for 6.4 hours a day, enabling teachers and parents to take action to keep children healthy.

Building Energy-Efficient Schools of the Future

Lowering energy usage is another area where IoT can have a positive impact. Below are a few case scenarios of how educational institutes benefited through the use of IoT:

- The NMC Horizon 2012 K12 report envisions a school experience where students are recognized as soon as they set foot on campus, saving teachers' time.

Digitizing and Enhancing Academic Tests & Assessments

IoT has the potential to replace ineffective and antiquated paper-based systems with anytime-anywhere high-stake assessments and examinations.

- Device-level security, built on biometric systems such as facial recognition, offers ways to ensure honesty in exams.
- Local devices, routers and gateways could potentially be enabled for exam-standard security in designated ‘Examination Zones’

IoT Idea - Testing

E-Assessment and Examinations

A growing number of organisations – such as New South Wales - are re-engineering their assessment systems to take advantage of new secure platform technologies. The example below shows Australian Science (ESSA) testing using practical experiments online.
GETTING STARTED WITH IOT FOR EDUCATION

Building the Curriculum

The first step on the IoT journey is to build and adapt curricula that takes all students on the pathway to becoming technically creative. This involves mapping knowledge, skills and understanding; technology application areas; and software & hardware to existing curriculum.

For example, the following curriculum framework offers sequential STEM learning that builds in layers:

- Electronics
- Computer Science
- Programming
- Robotics
- Manufacturing & Recycling
- Flight
- Construction
- Wearables
- Life Sciences
- Media & Entertainment

Creating New Learning Spaces

To take advantage of the rich learning opportunities that IoT technologies offer, Project Based Learning spaces need to be developed and equipped for a wide range of practical activities.

To incubate innovation, these spaces need to be equipped with:

- Technologies, ranging from sensors to servers, for:
  - Simulating Internet of Things scenarios
  - Enabling students to develop creative solutions for real-life problems
  - A spectrum of hardware & software to offer a creative ‘palette’ for learning

Leveraging IoT Building Blocks

Electronics

A good starting point is to get learners to work with basic switches, LEDs and motors on a solderless protoboard. Going ahead, more sophisticated solutions using transistors, capacitors, resistors and microprocessors can be built.

![Solderless Protoboard](image)

**Figure 6. Solderless Protoboard – a foundation for understanding and learning how to control the digital world around us**

Sensors

A wide range of sensors connect easily with development boards and protoboards, and can be used to measure a full spectrum of physical phenomena such as sound, magnetism, moisture, flow, light, proximity, and forces.

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A Typical IoT Curriculum
Data from sensors processed in a development board can be used to trigger events such as turning on a motor or valve. When combined with other components, complete systems – such as environmental control systems – can be built. Intel® Galileo is a development board designed specifically for education and makers.

One example of an embedded computer is the Intel® Edison. Despite its extremely small size, it can run a Linux® operating system and control a full range of devices such as sensors, actuators and motors, over wireless.

The Intel® Curie™ module can power a wearables solution the size of a button, and in a broad range of form factors - including rings, bags, bracelets, pendants, and fitness trackers.

Intel has a proven holistic model for transforming education. Our systematic approach delivers fresh insights, unique programs, and holistic solutions that help deliver student success. The Internet of Things encapsulates exciting new approaches to education and learning opportunities, which Intel embraces through our education programs and technology offerings.

According to *iot-analytics.com*, Intel is the market leader in the Internet of Things. With technology offerings in each layer of the IoT, an integrated IoT platform, and our education transformation expertise, Intel is uniquely placed to help you build your own ‘Internet of Learning Things’.

Contact your local Intel representative to discover what the Internet of Things can do for your organisation.

**RESOURCES**

- Arduino - http://arduino.cc
- Maker Community - http://makerspace.com
- IoT in Education, Invention-Based Learning curriculum, and kits - http://CLWB.org
- Fablab@School - https://tltl.stanford.edu/project/fablabschool
- Instructables, project ideas and instructions – http://www.instructables.com
- Intel in Education - http://goo.gl/[QUJeV
- Intel Education STEM Resources - http://goo.gl/yfbKJ1
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This Whitepaper is conceptualized and created by Intel in association with CLWB.org.