The TiRoLab Concept

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***Abstract*— At "Tiroler Roboter Labor", short TiRoLab, girls, boys, young women and men are introduced to the fascination of robots and, consequently, informatics and mechatronics as a means of building their self-confidence with regard to technical skills. We run a "hands-on lab" and develop robotics workshops for participants from kindergarten to all levels of formal education and beyond. This paper discusses the strategy behind this concept.**

***Keywords*— TiRoLab, robotics, education, kindergarten, school**

I. Introduction

The Austrian state of Tyrol does not differ from many other European regions in that it depends on highly qualified employees if it is to remain a competitive and attractive location for high-tech industries. International studies show that education is a key factor in attracting more young people to technical professions. The Austrian Chamber of Economics suggests offering active vocational training [1].

II. Background

Which profession or course of university study a young person decides to pursue depends on their social and personal environment [2]. A career path is often selected on the basis of stories and experiences related by family and friends.

Technology has acquired a bum rap with the general public: it is seen as a a pursuit for loners and math geniuses [3].

This is due to a general lack of information about technical training opportunities, careers, innovative companies and industry's very real need for skilled workers [4].

The Association of the Austrian Electrical and Electronics Industries in its exploratory study about "Shortage of engineers and choice of study [4]" gave exact recommendations for action (see Table 1).

TABLE 1
Recommendations for Action[4]

Item	Topic
1	Public communication on demand for employees with technical skills
2	Public relations and educational work on technical careers
3	Teachers as a key factor
4	Importance of family members and friends
5	Educational television

The MoMoTech trial [5] reviewed approx. 1.000 technology projects in Germany for their effect and efficacy and then suggested four basic levels of technical involvement (see Table 2).

TABLE 2
Levels of Technical Involvement [5]

Level	Topic
1	Encourage childlike curiosity and technical fascination
2	Convert curiosity into deeper technical interest
3	Taking the initiative to start technical activities
4	Develop a personal preference for a technical career

We decided to use LEGO Mindstorms NXT as our robotics platform for the following reasons:

Nearly everyone, whether child or adult, played with LEGO during their childhood and loved it. Therefore, it is not recognised as an education medium, but is seen as a toy to have fun with. This is a major advantage in bringing kids into contact with technology and arousing their curiosity.

Because it is based on LEGO Technic it is easy to build different robots, even ones that look like animals [6]! There is no need for screwdrivers or other tools, which enhances its appeal for girls.

The NXT kit comes ready to run with three motors and four sensors. They are easy to connect without needing soldering.

If greater mechanical stability or resolution is needed, the NXT kit components can be combined with Tetrix [7], a LEGO Technic compatible system with aluminium elements for construction, metal gears, RC-Servos and DC model craft motors.

A more detailed look at its hardware and software abilities shows the system's enormous flexibility:

Hardware

The NXT kit contains a programmable brick consisting of a 32-bit ARM processor at 48MHz, an 8-bit Amtel AVR coprocessor at 8MHz communicating via SPI, an LCD matrix display with 100*64 pixels, a Bluetooth and a USB2 interface, 8-bit sound supporting sample rates from 2–16kHz, three motor driver ports with encoder inputs and four sensor inputs I2C-capable with two digital IO lines and one analog input.

Input 4 can be used for RS 485 (IEC 61158 Type 4) communication and can run on a rechargeable lithium battery.

Commercial suppliers like Vernier[8], Mindsensors[9], HiTechnic[10], Dexter Industries[11] and Codatex[12] sell high-quality hardware sensors and actuators that can be used out of the box (selected examples are given in Table 3). At the date of publication more than 80 extensions were available. For a current list, please consult the suppliers' websites. NXT-G and RobotC drivers are usually included; some suppliers even support NXC, LeJOS and LabView drivers. With the wide range of available sensors even complex robots and technical experiments can be run.

LEGO provides a free available hardware development kit with all schematics and an open source software development kit of the firmware [13]. This enables users to build their own sensors or actors [14].

TABLE 3
EXAMPLES OF THIRD-PARTY HARDWARE EXTENSIONS FOR NXT

Supplier	Tool
Vernier	25g Accelerometer
Vernier	pH Sensor
Vernier	Turbidity Sensor
Mindsensors	Magic Wand
Mindsensors	3-Axis Acceleration Sensor
Mindsensors	8-Channel Servo Controller
HiTechnic	Compass Sensor
HiTechnic	EOPD Sensor
HiTechnic	Solderless Prototype Board
Dexter	NXTBee (Xbee)
Dexter	dGPS
Dexter	dSolar (2W and 4W Solar Panel, CapBank)
Codatex	RF ID Sensor

Software

The original programming software supplied with the commercial NXT set (or purchased separately for the educational NXT set) is NXT-G, a graphical programming IDE based on National Instruments LabView. Since the set was released in 2006 other open source and commercial programming tools became available. They can be divided into two main groups: those for which programmes are downloaded to the programmable brick (examples see Table 3) and those where the user programme runs on a PC or PDA (examples see Table 4) and communicates with NXT via USB or Bluetooth. PC-based programmes can draw on the PC’s full power. The overview is based on an updated review by team hassenplug [15]. Non-programmable PC- or PDA-based remote-control tools were not included, but can be easily located in a webseach.

TABLE 4
EXAMPLES OF NXT PROGRAMMING LANGUAGES BRICK-BASED

Name	Type	Licence	Debug
NXT-G [16]	Graphical	comm..	No
LabView [17]	Graphical	comm..	No
NXC [18]	C-like	OS	No
RobotC [19]	C	comm.	Yes
leJOS [20]	Java	OS	No
nxtOSEK [21]	C, C++	OS	Yes
IAR [22]	C, C++, Graphical	comm.	Yes
NXTGCC[23]	C	OS	Yes

Licence: comm.: commercial; OS: open source

TABLE 5
EXAMPLES OF NXT PROGRAMMING LANGUAGES PC-BASED

Name	Type	Licence	Debug
LabView[17]	Graphical	comm..	Yes
MS Robotic Studio[24]	Graphical	comm..	Yes
DialogOS[25]	Graphical	comm..	No
NXT Python[26]	Python	OS	Yes
Mathlab[27]	m Code	comm.	Yes
Simulink[27]	Graphical	comm.	Yes

Licence: comm.: commercial; OS: Open Source

There are three different products that can be used to run NXT robots in virtual worlds without a physical robotics kit. This enables the development of online robotics courses for kids with computer access but without robotics hardware:

- Microsoft Robotics Developer Studio [24]
- SimLejos with leJOS programmes
- Virtual Worlds with RobotC [28]

If the NXT is used to teach embedded developing, even JTAG debugging can be performed. The brick has to be opened and the JTAG connectors wired. Figures 1 and 2 show the author's NXT brick: JTAG-enabled (ARM and AVR processors) with additional reset button on front. A custom adaptor cable connects the frontside female connector and the standard debug header of the JTAG probe.

Figure 1: NXT with JTAG modification

Figure 2 NXT frontside with 1.27" female connector and reset button

The LEGO NXT kit is widely used for educational purposes (see Table 6). Its projects range from workshops for kids [29], demonstrating complex science projects like the Rosetta landing on a comet [30], to high-tech hardware extensions [31].

TABLE 6
LEGO NXT WORKSHOPS AND EDUCATIONAL PROJECTS

Project and Institution
Cooperation between LEGO and Tuffs University [32]
Carnegie Mellon Robotics Academy [29]
Roberta, Fraunhofer IAIS [33]
Rosetta, ESA [30]
H.A.L.E, University of Nevada Reno [34]
TUMlab, TU Munich, Deutsches Museum Munich [35]
LEGO Beyond Toys, TU Eindhoven [31]
LEGO Engineering from Kindergarten to College, Tuffs University [36]

There are exciting national and international LEGO NXT robotics competitions (see Table 7) that serve to promote technology in the public eye and motivate the competition participants.

TABLE 7
ROBOTICS COMPETITIONS WITH LEGO NXT

Competition
FLL, First LEGO League [37]
RoboCup [38]
World Robot Olympiad [39]
RobotChallenge [40]

III. APPROACH

We use robotics kits as a tool to generate enthusiasm for technology for the following reasons:

Robot kits are a fast and easy way to enter mechanics, electronics and programming. A beginner's achievements become visible very quickly.

Robots are real hands-on items that make technology understandable and let formulas come to life so they are no longer experienced as abstract entities.

The complete development of a robot trains complex system development skills. It begins with a precise identification of the requirements, draft planning, construction, programming, testing, optimisation and finally documentation of the finished robot. This process calls for interdisciplinary thinking and coordination so that hardware, software, electronics and mechanics all work together.

Greater efforts are needed to promote sustainability. This is why the TiRoLab concept starts in early kindergarten using curiosity and the natural fascination of exploring new things to give small children a positive attitude toward technical concepts like robots. As the kids grow up we accompany them through school, deepen their knowledge and demonstrate capabilities for the next step into a technical profession or a university degree in engineering.

Robotics Workshops

A team consists of two kids with two computers and one LEGO NXT robotics kit. Kids should have the opportunity to incorporate their own ideas as well as to act as a team when constructing the robot.

Modern teaching means incorporating gender aspects. A nice side-effect is that girl-sensitive concepts work just fine with boys, but not vice versa [41].

To present the workshop's goal we use storytelling techniques instead of technical problem definitions. For example:

"A frog is hiding in the pond, waiting for a dragonfly. When the frog sees the dragonfly, it jumps out to catch it." instead of:

"The robot is on standby at position 1 and waits for sensor input 3. If the value exceeds the threshold, motors A and B turn on forward for 2 seconds."

Decorative material like neon bricks, colored paper, feathers and adhesive tape help kids turn technical components into fantasy creations.

Instead of holding competitions, we encourage the kids to run presentations with their robots in order to enhance communication between teams.

Workshop duration depends on the complexity of the challenge and on the age group, e.g. in kindergarten it is limited to 50 minutes. Older kids can attend half- or full-day workshops. Summer camps can even hold big projects that run up to a week.

The result is that kids learn to use a computer as a tool to implement their creative ideas, and not merely as a passive game station.

Diploma and License

When a child finishes a workshop she or he will receive a diploma with a picture of her- or himself, the built robot and details on the workshop. The diploma includes a separate licence (like a driving license) that documents the training level achieved. This is represented by a letter for the particular age group (A-H, see Table 8) and a number that increases with the level of complexity of the challenge mastered (1-17, see Table 9).

With the diploma and license the child can demonstrate its success to family and friends and is thus motivated to proceed to the next level.

TABLE 8
AGE-BASED GROUPS

Group	Designation	Age / years
A	Kindergarten	5 – 6
B	Primary School	7 – 10
C	Junior High School	11- 14
D	Senior High School	15 – 18
E	Apprentices	15 +
F	University Students	17 +
G	Adult hobbyists	18 +
H	Adult professionals	18 +
I	Experts	25 +

TABLE 9
COMPLEXITY-BASED LEVELS

Level	Content
1	Teach-In Programming
2	Simple Sequences
3	Using Display and Sound
4	Loops
5	Read and Display Sensor Values
6	Wait for Sensor
7	Conditional Branch
8	Variables and Calculations
9	Data Logging
10	Data Visualising
11	Robot-to-Robot Communication
12	Robot-to-PC Communication
13	Feedback Loops
14	Build Sensors and Actors
15	Embedded Programming
16	Build Complex Hardware
17	Build Realtime Applications

The maximum attainable level depends on the age group: for kindergarten youngsters it is A3, primary school kids B7, junior high school kids C12, senior high school kids E14, apprentices and above (F to I) up to level 17.

Teachers and Schools

Teachers are important disseminators for the project. The best practice example would be for a robotics lesson to be prepared in school, embedded in the curriculum, and for the kids to build their robot projects at TiRoLab with post-processing of the learning units back at school.

We will run teacher training sessions to enable the teachers to hold their own robotics lesson at school.

We will offer schools a limited number of robotics kits and notebooks that can be rented for one to eight weeks for a nominal fee. In this way they can test robotics lessons in their own classrooms without having to make a big investment.

Parents

We will also take family and friends on board, because social environment is a major factor in kids' development. Parents are encouraged to drop by before the end of the workshop and attend their child's robot presentation.

Information

On the TiRoLab website we will provide information about schools with a technical focus, training opportunities, resources for independent learning, apprenticeships, the high-tech industry in Tyrol, continuing education and technical university degree programs in Tyrol and job prospects.

IV. CONCLUSIONS

While some of the ideas behind the TiRoLab Concept are new, many of them were adopted from and inspired by outstanding projects like those of Tuffs University or the MIT Media Lab with Lifelong Kindergarten and trials like MoMoTech, among many others.

We acquired early experience by running robotics workshops for medical students in the elective course “Theoretical Surgery” and at the Kids and Youth Academy at Innsbruck Medical University running workshops for junior high school and kindergarten kids.

We are working hard to move TiRoLab from the drawing board to a true robotics lab by the start of 2012.

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