HSci2010 - 7th International Conference on Hands-on Science

Inspiring Science Learning

Proceedings of the "Learning with ATLAS@CERN" Workshops

Rethymno, Greece, July 25-31, 2010

Education and Culture DG
Lifelong Learning Programme
EACEA Education, Audiovisual & Culture Executive Agency
Learning with ATLAS@CERN
HSCI Hands on Science

HSci2010 - 7th International Conference on Hands-on Science

Inspiring Science Learning

Proceedings of the "Learning with ATLAS@CERN" Workshops

July 25 - 31, 2010

The University of Crete campus at Rethymno, Greece

Published by **Ellinogermaniki Agogi**

Editor:

Angelos Lazoudis
Sofoklis Sotiriou

Artwork:

Vagelis Anastasiou

Learning with ATLAS@CERN project is carried out within the framework of the LLP-ICT programme and is co-financed by the European Commission

Project number: 143719-LLP-1-2008-1-GR-KA3-KA3MP

Printed by **EPINOIA S.A.**

ISBN Number: 978-960-473-219-7

Preface

The Lifelong Learning Project "Learning with ATLAS@CERN" (2008-2010), supported by the EC, focused in the provision, implementation and dissemination of an innovative pedagogical framework which aimed to create an effective "dialogue" between scientific research and communities, at the moment that the new gigantic detector ATLAS started its operation at CERN, to explore the fundamental building blocks and forces of nature, and to probe deeper into matter than ever before. The project realized a reversal of science teaching pedagogy from mainly deductive to inquiry-based approach that provided the means to increase interest in science. The project approach emphasized curiosity and observations followed by problem solving and experimentation in both real and virtual settings. These pedagogical concepts and learning practices were addressed by implementing a set of missions (learning scenarios) tailored to the needs of the diverse groups of learners, employing advanced and interactive visualization technologies and also personalized ubiquitous learning paradigms in order to enhance the effectiveness and quality of the learning process. In the framework of these missions, users were able to use a series of educational analysis tools that allowed them to manipulate data and make their own discoveries. A web based educational environment http://www.learningwithatlas-portal.eu/ was developed to facilitate the access to the project's results.

Towards the end of the project a series of dedicated international workshops were organized in order to promote the dissemination of the results. These included hands-on workshops where the participants had the opportunity to use the tools, developed by the project, online in the computer laboratories. The workshops/talk sessions were organized under the auspices of the 7th International Conference on Hands-on Science "Bringing the Science and Society gap", on July 25-31, 2010 at the University of Crete campus in Rethymno, Greece (http://www.clab.edc.uoc.gr/hsci2010/). In parallel, an international Call for Papers was launched, and the talks presented at the conference appear in the present edited volume on "Inspiring Science Learning": This includes contributions from partners of the consortium as well as from people working on relevant issues around the world and on one hand help the project team to gain an overview of currently deployed initiatives in relevant areas and on the other hand provide an excellent opportunity to promote the project results to the interested communities.

Prof. Christine Kourkoumelis
University of Athens

Inspiring Science Learning: Designing the Science Classroom of the Future

Sofoklis Sotiriou
Ellinogermaniki Agogi
D. Panagea Str, GR-15351 Pallini, Greece
sotiriou@ea.gr

Abstract

Powerful methods for scaling-up and transferring pilot implementations and for evolving the public's conceptions of learning and schooling are essential to take full advantage of the opportunities ICT's pose. This work describes what may be its key contribution to the evolution of schools innovation and improvement: a new approach to stimulating, incubating, and accelerating innovation, which is strongly driven by users' needs. The aim of this work is a) to capture what we know so far about the process of encouraging schools to become more innovative b) to describe the Discovery Space Innovation Model which is built upon these understandings and c) to describe the practical programme of work which utilizes this model. Taking advantage from the current reform efforts in science and mathematics education in many

European countries and the implementation of some major re-schooling initiatives, our aim is to develop an innovative science and mathematics learning environment, which integrates modern technologies with the aim to create an open technology-enhanced classroom that builds on the strengths of formal and informal teaching and learning strategies in ways that can support learning of all individual students. This environment is embedded with interactive learning artifacts and assessment tools. 100 such classrooms have been set in operation in the most innovative schools in Europe. If we want a powerful innovative culture in schools which is self-sustaining we have to empower system-aware practitioners, working ever more closely with the service users, to create it. And to avoid simply creating interesting but isolated experiments, we have to design in collaborative ways of learning and enquiry between professionals – a "pull" rather than "push" approach.

Keywords

Advanced Technologies, Practitioner Led Innovation, Science Education.

1. Introduction

The Information and Knowledge Society has emerged as a result of technological advancements of the World Wide Web, the Internet and mobile communications over the last two decades. These technological developments have had; and still have direct impact to every aspect of our personal and social life, thus changing the way we communicate, collaborate, work and learn. Europe has been a world driving force when it comes to these technological developments, however, in many cases European Member States have fall behind in adopting the necessary societal re-organisational changes needed in government, education, health care and cultural preservation. This can be a critical issue for the future of European Union and the future of its Member States within the complex global challenges of the 21st Century.

When it comes to the field of education, this lack of social innovation becomes even more troubling, due to the fact that failing to "re-engineer" our national and European educational systems, effects significantly all other areas of social and economical development, jeopardising Europe's position in the global knowledge-based society. Indeed, Education seems to be a social activity still struggling to improve up to the societal anticipated expectations. Especially, schools appear to remain almost unchanged for the most part despite numerous efforts and investments in technology, teachers' training and infrastructure. Yet, the way we organise schooling and provide education remains basically the same. To put it in another way: "we still educate our students based on an agricultural timetable, in an industrial setting, yet telling students and teachers they live in a digital age".

During the past years, several reasons have been identified separately as possible distractions in aligning schools operations and results to the ones anticipated by the 21st Century Societies. The most highlighted ones being: lack of funds, not enough computers in the classroom, little interest from students and parents, out of date teaching practices, poorly trained teachers, and even a fundamentally flawed way to measure performance at schools.

Many national and European initiatives have been undertaken to tackle these issues separately. Yet, the improvement has been marginal, if any at all. We believe that a holistic approach to the re-organisation of Schooling is needed, rather than sporadic and isolated efforts. To this end, many different organisations with high quality and unique expertise in their field have decided to join forces in a European effort to propose a scientifically grounded, technological sustainable and organisationally disruptive plan for the Technology-enhanced Classroom of the Future that will give to all parties involved in schooling a motivation for change. This is our Discovery Space.

2. Supporting and improving educational practices in science and mathematics education

The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report [1] brought science and mathematics education to the top of educational goals of the member states (following similar actions in US in 1996 [2], [3]). The authors argue that school science teaching needs to become more engaging, based on inquiry based and problem solving methods and designed to meet the interests of young people. According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at schools. Although the crucial role of positive contacts with science at early stage in the subsequent formation of attitudes toward science is identified [4], traditional formal science education too often stifles this interest and, therefore, may negatively interact with the development of adolescents' attitudes towards learning science. Kinchin [5] pointed out that the tension created between objectivism (the objective teacher-centered pedagogy) and constructivism (the constructive and student-centered pedagogy) represents a crucial classroom issue to influence teaching and learning. The TIMSS (Third International Mathematics and Science Study) 2003 International Science Report [6] specifically documented that internationally, the three most predominant activities accounting for 57 percent of class time were teacher lecture (24%), teacher guided student practice (19%), and students working on problems on their own (14%) in science classes in the European countries participating in the study.

Therefore, it appears that the current science classroom learning environment is often a mixture of divergent pedagogies and diverse students' orientations or preferences [7], [8]. The fact is that there is a major mismatch between opportunity and action in most education systems today. It revolves around what is meant by "science education," a term that is incorrectly defined in current usage. Rather than learning how to think scientifically, students are generally being told about science and asked to remember facts [9]. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part of the education of students everywhere.

In addition to the aforementioned issues, science learning environment (classroom and lab) seems to have not gone through any significant changes for the past decades. Recent research on learning and instruction has substantially advanced our understanding of the processes of knowledge and skill acquisition [10]. However, school practices have not been innovated and improved in ways that reflect this progress in the development of a theory of learning from instruction. School practices in a realistic sense are cantered on school learning environment. It is generally recognized among practitioners that our school science learning environment has neither been innovated nor reformed to reflect these new knowledge on learning and teaching. Moreover, modern technologies beyond just the use of computers and internet in the school have not fully integrated/incorporated in current science learning environment.

According to the recent report "Science Education in Europe: Critical Reflections" [11] the deeper problem in science education is one of fundamental purpose. Schools, the authors argue, have never provided a satisfactory education in sciences for the majority. Now the evidence is that it is failing in its original purpose, to provide a route into science for future scientists. The challenge therefore, is to re-imagine science education: to consider how it can be made fit for the modern world and how it can meet the needs of all students; those who will go on to work in scientific and technical subjects, and those who will not [12]

In this framework the classroom of the future should provide more challenging, authentic and higher-order learning experiences, more opportunities for students to participate into scientific practices and task embedded in social interaction using the discourse of science and work with scientific representations and tools. It should enrich and transform the students' concepts and initial ideas. These ideas could be both resources and barriers to emerging ideas. The classroom of the future should offer opportunities for teaching tailored to the students' particular needs while it should provide continuous measures of competence, integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is compelling to students.

3. Introduce meaningful ICT-based innovation for quality learning and teaching

The classroom of the future features a collection of interconnected e-systems and Web-enabled services to facilitate teaching, learning and assessment. All these new systems will require interfacing with key existing legacy systems that are characterized by different organizational structures. Creating an IT infrastructure plan for the school of the future isn't just about plugging in the latest and greatest—it's about balancing competing forces. Educators and technologists need to reach for the possibilities of the future, plan for the realities of the present, and account for limitations created by the past—all at the same time. To our view three complementary interfaces shape the technological infrastructure of the science and mathematics classroom of the future:

The familiar "world to the desk top" interface, providing access to distant experts and archives (see Figure 1), enabling collaborations, mentoring relationships, and virtual communities-of practice. This interface is evolving through initiatives such as Web 2.0. The work focuses on the support of learning communities where teachers and learners are helping each other, or work together on certain problems. In order to monitor, analyze and support those learning communities we need to implement tools which capture usage and interaction. We also need personal and digital agents that help to build up a learning context based on content in order to support teachers and students.

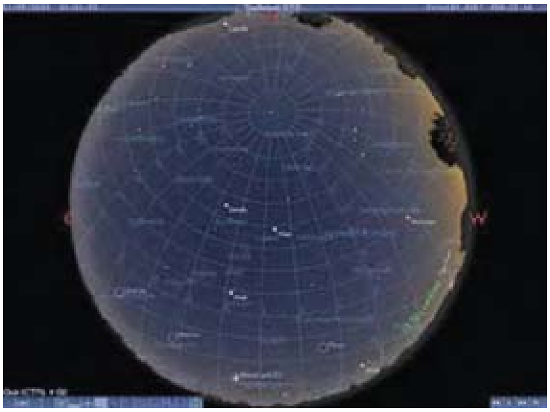


Figure 1. *The Discovery Space Observatory provides access to a global network of robotic telescopes and supplies free resources for science and mathematics education.*

Interfaces for "ubiquitous computing", in which portable wireless devices infuse virtual resources as we move through the real world [13]. The early stages of "augmented reality" interfaces are characterized by research on the role of "smart objects" and "intelligent contexts" in learning and doing. Those interfaces are intended to provide the freedom to learn "on site" – get into a real problem context and learn on virtual data. Therefore we need mixed reality cross platform devices, to create interfaces that seem to inhabit the users' environment. Those tools should be seamlessly integrated into the users' world. The interfaces should be light weight and least intrusive. The users have to be able to interact within their augmented environment in a most possible intuitive way. In order to create such a ubiquitous environment interfaces should be available at any time and any place where the user can be. Thus one has to build on mobile devices and visible (e.g. QR-Tags, Semacode) and ubiquitous tracking techniques, such as GPS or NFC (near field communication), inertial tracking and a complementary computer vision tracking. One major aspect of those devices is interactivity that allows users intuitive interaction.

Figure 2. *Kick life into the Classroom with the Lab of Tomorrow System: Playing with a "smart" ball with embedded sensors, gathering and manipulating experimental data of real life activities.*

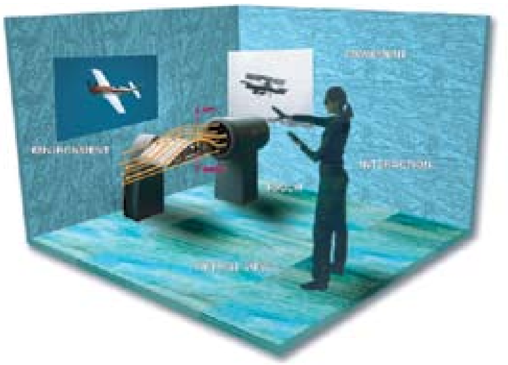


Figure 3. *Visualizing the invisible using the CONNECT system: The visualization of natural phenomena could support the conceptual change.*

Immersive and multi-user virtual environments interfaces, in which users and participants' avatars interact with computer based agents and digital artifacts in virtual contexts. The initial stages of studies on shared virtual environments are characterized by advances in Internet games and work in virtual and augmented reality. In order to implement "Virtual Labs" and multi user environments we demand a VR interface, an underlying context system, a high bandwidth network communication, as well as a hypermedia database. The most important part of a virtual environment is the interface through which users are able to enter the virtual world. Immersion plays a key role, thus all senses need to be stimulated properly. Moreover, it is fundamental for the effect of immersion that the system should behave in a way the user expects it to behave. This is, interaction has to be intuitive, user tracking should be accurate, this is, the system output should be realistic if necessary.

Immersive interfaces can foster educational experiences that drawn on a powerful pedagogy: contextualized learning. Situated learning requires authentic contexts, activities and assessment coupled with guidance from expert modelling, mentoring and "legitimate peripheral participation" [14].

The technologies in this type of innovative classroom should be intelligent, interactive, individualized and integrated as the following: (1) intelligent: the classroom technology should be highly context-aware and adaptively support tasks that originally require excessive human interventions; (2) interactive: the classroom technology should facilitate interactions between the teacher and the students; (3) individualized: the classroom technology should react differently in accordance to individual user; and (4) integrated: the classroom technologies should be integrated as one system instead of many separate systems.

Technologically-based applications could effectively support the pedagogical requirements for the future science and mathematics classroom, as they were described in the previous paragraphs. Moreover, research has demonstrated empirically the effectiveness of such applications. The question is why has this potential not been realized? Several reasons are very clear: Current schools and classrooms are not designed in ways that can utilize the potential of technology; there is lack of appropriate preparation of teachers in the use of technology both at the pre-service and in-service levels leading to anxiety and low motivation to integrate technology in classes.

4. Understand and managing underlying change process

Although most of the European educational systems remain highly centralized, ICT policy implementation remains optional and allows for substantial discretion to the implementers, and for a "backward approach" leading to goal and role definitions in the field. In the light of such open-ended and general ICT policies practitioners at the micro level and the communities of implementation they generate as a response to ICT policy can be proved critical in ICT integration into the system. Our work aims to enhance the role of such communities. An important concept underlying the proposed approach is the notion of the community of implementation, which is regarded as a type of community of practice. Within our research work in particular, communities of implementation are regarded as self-reproducing, and evolving entities emerging within the school settings as a response to an externally developed policy. Various authors emphasize the importance of communities of practice for organizations [15], [16] and therefore communities of implementation are considered as a purposeful strategy for spreading innovations. For teachers, innovation is a high risk activity and the incentives are few [17]. In a system where the centre has been the innovator, practitioner compliance understandably becomes the habit. The dynamic of change in education in Europe has been described in terms of a set of shifts, first, from "uninformed prescription" (in the 1980s); to "informed prescription"; then towards practitioner-led change [18]. This last was seen as the key to self-sustaining, rapid improvement. It is within this context, that our work aims to take forward the agenda of practitioner-led change at a European level. This work describes what may be its key contribution to the evolution of schools innovation and improvement: a new approach to stimulating, incubating, and accelerating innovation, which is strongly driven by users' needs. At this level our work is focusing on three aspects: to capture, briefly, what we know so far about the process of encouraging schools to become more innovative; to describe the Discovery Space innovation model which is built upon these understandings; and to describe the practical programme of work which utilizes this model.

There is plenty of evidence pointing to the difficulty of incentivising and empowering teachers to engage in innovation, especially in tightly accountable systems based on performance targets. In education there is no shortage of energy and expertise, and certainly no lack of commitment or moral purpose amongst teachers. How could we support them, and give them the creative space and incentives they need to be innovative? What sort of interventions could both release professional imagination, whilst encouraging work that is disciplined and system relevant? How can the system learn from the resultant innovation and its process characteristics so that these can be taken to scale? How can busy, performance-driven teachers become aware of approaches and techniques which are emerging in other sectors - private and voluntary, as well as across public services more widely? It is enormously difficult in practice to be fully alert to developments and methods outside one's "zone of operation" (and sometimes even within it) which offer improvement potential. Some school leaders do manage to scan other horizons for ideas with transfer potential. How far can this be done on their behalf, to shortcut the investment of time, and also optimize the scope for adaptation?

5. Assisting behavioural change and professional development of teachers

Asking teachers to follow advanced ICT methods in their everyday teaching practice constitutes a major behavioural change and at the same a significant development opportunity for them. The task at hand is to manage this change in a uniform way, allowing teachers to realize the potential of the opportunity offered by the Discovery Space initiative, take ownership of their contribution and maximize the output for both the project and themselves. In a review paper [19], McKinsey management experts identify four key prerequisites for accelerating and establishing change:

A purpose to believe in: "I will change if I believe I should": The first, and most important, condition for change is identifying a purpose to believe in. In our case, we must persuade teachers of the importance of scientific literature in terms of social value, importance to their students and personal achievement through learning and teaching these important subjects. We must carefully craft a "change story" underlining the benefits that the project can offer to all the involved actors. Furthermore, we must cultivate a sense of community, making the teacher feel part of a cohesive multi-national team. This sense of belonging will prove very important for motivating teachers and asking them to take then next, possibly "painful" steps, of learning new skills.

Reinforcement systems: "I will change if I have something to win". From a pure Skinner behaviouristic point of view, changing is only possible if formal and informal conditioning mechanisms are in place. These mechanisms can reinforce the new behaviour, penalize the old one or, preferably do both. In our case, we can use informal reinforcement patterns in order to make teachers commit more to our project. A short list of such methods could include competitions, challenges, promoting the best teacher created content, offering summer schools as rewards, etc.

The skills required for change: "I will change if I have the right skills". A change is only possible if all the involved actors have the right set of skills. In the case of the Discovery Space project, the implementation team should make sure that the training program is designed in such a way that teachers acquire all the skills they will need, both technical and pedagogical.

Consistent role models: "I will change if other people change". A number of "change champions" will need to be established, acting as role models and change agents for the community of teachers. These very active and competent teachers will be a proof of concept for their colleagues that the change is indeed feasible, acceptable and beneficial for them. To achieve that we will have to identify the high flyers among the participating teachers and pay special attention into motivating them, supporting and encouraging them.

All four will specifically be addressed in each of the participating schools of the Discovery Space network. Additionally our team collaborate closely with teachers to develop a set of support services which help teachers to implement the necessary changes, to develop the diagnostics and intervention skills necessary to best plan and then diffuse innovation in their own contexts. An effective training approach provides the starting point for equipping teachers with the competences they need to act successfully as change agents, developing a language/terminology necessary to describe the dynamics of change processes, and making them able to recognize different forms of resistance and addressing it in their own context. At the same time it provides a common basis/experience for "connecting" teachers across schools, within and across national boundaries – engaging them in an ongoing exchange of experiences across school, regions and countries.

6. The Discovery Space Innovation Model

Taken together, the evidence set out above and the questions and issues it raises suggest some assumptions, which in turn have influenced the educational design of the Discovery Space approach.

The combination of a methodology derived from the available evidence base, with a mobilized group of empowered practitioners motivated by a compelling purpose, supported by dedicated innovation agencies in partnership with the key national bodies, will result in emergent Discovery Space implementation scenarios for the future science and mathematics classroom which will have system significance.

The right group to work with will be drawn from those practitioners who are already pushing at the boundaries of current practice in a chosen area. They will be well aware of practice deemed "best" – will perhaps have generated/adopted/adapted it. But they will be conscious too of its limits, and will have experienced the need to push on further, or in new directions. Skilled and self-confident, these are likely to be practitioners whose deep immersion, and success, in their work gives them the platform upon which to contemplate risk and to lead others. Visionary and energetic, their ideas spring from immersion in practice: not in theory or in ideology. They may well be alert to and interested in such fields, but the practical applications for their own "day jobs" are paramount. Indeed, it is likely that they have a wide field of vision. They will have a lively interest in the overall direction of the service in which they work, and be constantly scanning the environment for ways in which both to influence and exploit it.

Such an innovation programme holds great potential. If we want a powerful innovative culture in schools which is self-sustaining we have to empower system-aware practitioners, working ever more closely with the service users, to create it. And to avoid simply creating interesting but isolated pockets of experimentation, we have to design in collaborative ways of learning and enquiry between professionals – a "pull" rather than "push" approach.

Perhaps the most significant evidence to be considered in the search for how to foster practitioner-led innovation is that concerning the enablers and barriers. Innovators have some obvious needs including legitimation and support; and recognition and incentives (which need not be financial). They suggest also that the availability of experimental "space" can be critical – especially when it is closely tied to the involvement of end-users [20]. Barriers of course include the lack, or reverse, of the above conditions. But interestingly – from the perspective of the design of a support programme – also identified [21] is an over-reliance on high-performers as sources. This finding is difficult to interpret. At one level, such practitioners are invested in their already-successful approach; at another, they are well-placed to know the limits of current "best practice". To embark upon radical innovation requires, one could argue, confidence based on a secure reputation. Innovative initiative is likely to be regarded, (as Schopenhauer pointed out in relation to any "new truth') first with ridicule, then with violent opposition. Finally the outcome will be regarded as self-evident.

The underlying principles of the Discovery Space project approach are:

Creative community involvement: The consortium aims to create conditions for the development of teachers, new ideas, effective participation and new tools and applications to move the community into positive participation in a more equitable digital future. For this to happen the project will be led by interested stakeholders, on the basis of a strong process of creative educational community involvement. Indeed we should not try to force development into a pre-determined mold. The project team will not be repeating what has been done before. Thus creative community involvement plays a critical role in this project.

Design-based research: Design-based research methods respond to emergent features of the setting. Micro-analyses of teachers and learners interactions with activities based on this principle will enable redesign and refinement of the activities and ultimately refinement of the underlying interest-driven learning framework. Thus, emergent behaviours of learners in response to activities drive the development of both intervention and theory, which would have been unimaginable in the absence of real learners' choices. Finally, in a design-based research, practitioners and researchers work together to produce meaningful change in contexts of practice.

Such collaboration means that goals and design constraints are drawn from both the local context and the researcher's agenda, addressing a concern of many reform efforts. Engaging in such partnerships across multiple settings can uncover relationships between the numerous variables that come into play in learning contexts and help refine the key components of an intervention. In particular, these partnerships can help us distinguish between a "lethal mutation" [22] -a reinterpretation that no longer captures the pedagogical essence of the innovation- and a productive adaptation -a reinterpretation that preserves this essence, but tailors the activity to the needs and characteristics of particular learning environments-. Sustainable innovation requires understanding how and why an innovation works within a setting over time and across settings, and generating heuristics for those interested in enacting innovations in their own local contexts. In the early stages of the process, scenarios are used in order

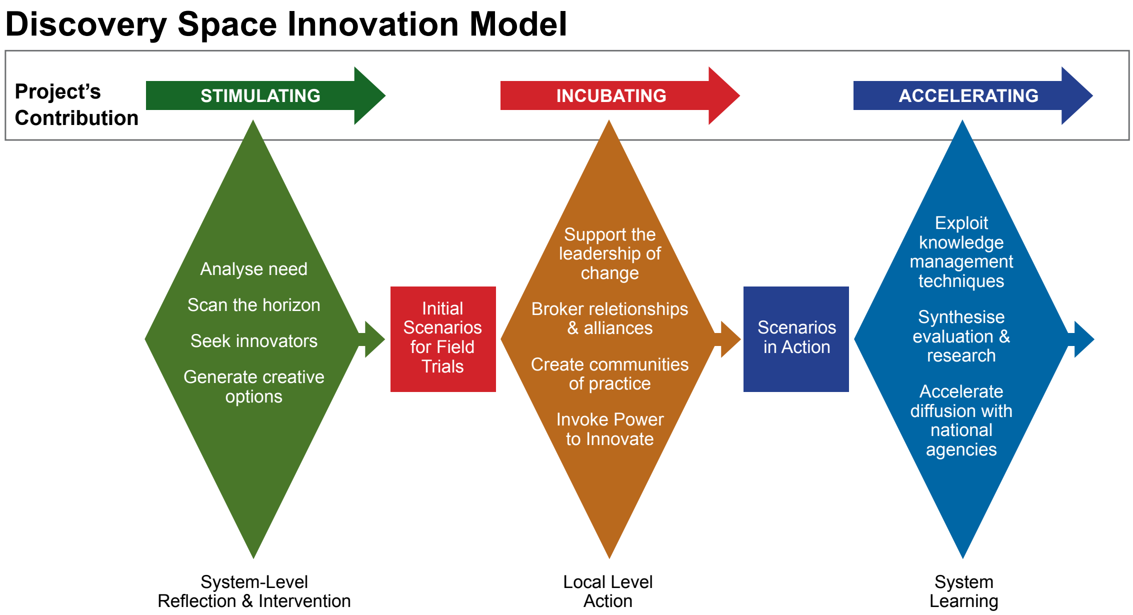


Figure 4. *The Discovery Space Innovation Model will facilitate the introduction of innovation in a wide network of schools.*

to plan the methodology and to characterize episodes or a sequence of activities (like in a story). These "stories" provide the context within which activities are carried out, so as to give us insights about the needs, difficulties and motivations that users have in particular contexts. Key elements for the Discovery Space scenarios are the users and their resistance to change, their goals, their needs, the sources of information accessed during the activities, and the information generated by the users themselves. Emergence of a community of inquiry does not happen by itself and does not emerge until considerable group dialogue takes place.

Teaching and learning techniques and activities that promote student-student interaction and that focus learning on problem solving and on applications to real-world experience, will enhance the development of such communities [23].

The design of the project's approach for the introduction of the innovation is shown in Figure 4. Each phase is deliberately represented visually by a diamond: it seeks to capture the movement within each phase from an initial focus broadening to a wider set of generated possibilities, which subsequently become refocused.

The design process is at system level, and consists of reflection – followed by intervention – to clarify the specific practice to be the focus for innovation. The work of analysing the need and scanning the horizon may be of theoretical and policy interest, but the proposed approach seeks to involve potential innovators (including users) in these processes from the start, as a platform for action. Assembling the right practitioners – diverse, accomplished, motivated and already poised to drive forward if the right conditions obtain – is key if they are to be mobilised to embark on significant change. Generate Creative Options is focused on bringing such practitioners together with innovators and provocateurs from other sectors, and with users, to generate creative options for the project field trials. Activities might include focus groups, creative workshops, futures thinking, service design workshops, and the use of open space technology.

A very demanding task of the project's implementation is expected to be the monitoring of the users' activities. In several of our previous projects in the field of application of advanced learning systems, evaluation of the learning environments has been carried out and formative, summative, qualitative and quantitative approaches have been developed and improved. There is though an ongoing demand to improve this methodology in a reverse participation: We are used to ask for a participatory system design in the direction that users or other selected stakeholders participate in the design process, but we are not very much used to the perspective that the evaluation process itself is subject to an intensive participation process influenced by designers and users. This is the case in the Discovery Space approach. This hopefully will not only give new insights into learning processes but also into evaluation methods. Our work evolves through a systematic, multi-step assessment process involving the collection and interpretation of data. The project's assessment places greater emphasis on the results of assessment procedures that sample an assortment of variables using diverse data-collection methods. Thus all aspects of the proposed approach are measured using multiple methods such as performances and portfolios, as well as interviews and questionnaires.

7. Conclusions – Next Steps

The described Innovation Model has been tested in practice in numerous school environments and it proves that facilitates a shift in pedagogical practice among the staff, enabled by pervasive access to ICT throughout the school. The Discovery Space approach lays the groundwork with a technical infrastructure supported by continuing efforts to introduce new ideas, support the development of technological fluency, methodologies to help harness creativity, and support to develop a pathway for the effective use of advanced technological applications in schools. The new technologies open the possibility of harnessing the enormous scientific and technological progress that has been made in the last five decades (in various fields of science and technology), by placing it at the service of one of the most important sectors of our societies.

Through the creative use of the new technologies and the learning processes they can generate with respect to local school problems, we can address the challenge of the "social appropriation of knowledge" seeking to empower teachers and students through this knowledge and to develop technologies that reflect the school needs. Additionally, the proposed educational approach can make a significant contribution to the development of self-esteem, an increased "sense of belonging", and an improved perception of one's own capacity to solve problems and contribute to the "construction of the surrounding community". These factors have been clearly related to the development of "social capital" and a greater degree of conviviality and peace. Footcloth the school component and the community dimension of the project place an emphasis on developing certain key values and attitudes that play an important role in this process, such as the capacity of team work and a spirit of collaboration as a way of developing learning networks and communities.

8. Acknowledgements

The Discovery Space initiative builds on the outcomes on numerous projects and initiatives in the field of technology supported science education. The author wishes to thank all the colleagues who have worked in these projects effectively introducing innovation in science classrooms in many European schools during the last 10 years. The Discovery Space approach has been significantly affected from their valuable contributions and experimentations.

9. References (and Notes)

[1] Rocard M. et al, EC High Level Group on Science Education (2007). Science Education NOW: A Renewed Pedagogy for the Future of Europe, ISBN 978-92-79-05659-8.

[2] Committee on Science Learning, Kindergarten through Eighth Grade, Richard A. Duschl, Heidi A.Schweingruber, and Andrew W. Shouse, Editors: Taking Science Back to School: Learning and Teaching Science in Grades K-8 (1996).

[3] Education Development Center (EDC), Center for Science Education (2007). Publications and OtherResources Resulting from a Synthesis of Research on the Impact of Inquiry Science Instruction, Retrived June 11, 2010 from: http://cse.edc.org/products/inquirysynth/default.asp

[4] PISA 2006 Science Competencies for Tomorrow's World. Retrieved June 11, 2010 from: http://www.pisa.oecd.org

[5] Kinchin, I. M. (2004). Investigating students' beliefs about their preferred role as learners. EducationalResearch, 46 (3), 301-312.

[6] Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., & Chrostowski, S. J. (2004). TIMSS 2003 International science report. Boston, MA: TIMSS & PIRLS

International Study Center, Lynch School of Education, Boston College.

[7] Chang, C. Y., & Tsai, C.-C. (2005). The interplay between different forms of CAI and students' preferences of learning environment in the secondary science class. Science Education, 89, 707-724.

[8] Chang, C. Y., Hsiao, C. H., & Barufaldi, J. P. (2006). Preferred-actual learning environment 'spaces' and earth science outcomes in Taiwan. Science Education, 90(3), 420-433.

[9] SCIENCE, Vol. 323, 2 January 2009, www.sciencemag.org

[10] Rodger W. Bybee, Leslie W. Trowbridge, Janet Carlson Powell: Teaching Secondary School Science:Strategies for Developing Scientific Literacy 2008 (9th Edition). ISBN -13: 978-0-13-230450-4.

[11] Osborne, J. & Dilon, J. (2008). Science Education in Europe: Critical Reflections. A report to the Nuffield Foundation.

[12] Kali, y., & Linn, m. (2009). Designing Coherent Science Education: Implications from Curriculum, Instruction, and Policy. Teachers College Press.

[13] Druin, A. (2009). Mobile Technology for Children: Designing for Interaction and Learning. Morgan Kaufmann Publishers Inc.

[14] Sotiriou, S. & Bogner, F. (2008) Visualising the Invisible: Augmented Reality as an Innovative ScienceEducation Scheme Advanced Science Letters, Vol 1, 114-122, 2008

[15] Lesser, E. and Storck, J. (2001), 'Communities of practice and organisational performance', IBM Systems Journal, Vol 40, No 4.

[16] Wenger, E., McDermott, R. & Snyder, W., (2002). Cultivating Communities of Practice, A Guide to Managing Knowledge, Harvard Business School Press, Boston Mass.

[17] Hannon, V. (2009) "'Next Practice' in education: a disciplined approach to innovation" Innovation Next Practice (2009) See The Innovation Unit website: www.innovation-unit.co.uk

[18] Barber, M., 2002. The Next Stage for Large Scale Reform in England: From Good to Great. Background paper for the Federal Reserve Bank of Boston 47th Economic Conference, 'Education in the 21st Century: Meeting the Challenges of a Changing World' (19-21 June 2002).

[19] Lawson, E. and Price C. (2003)"The psychology of change management", The McKinsey Quarterly 2003 Special Edition: The Value in Organization, p. 30- 41.

[20] Social Innovation: what it is, why it matters and how it can be accelerated (2006) The Young Foundation.

[21] Albury, D., January 2005. Fostering Innovation in Public Services. Article in Public Money & Management Journal.

[22] Brown, A.L., & Campione, J.C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), Innovations in learning: New environments for education (pp. 289-325). Mahwah, NJ: Erlbaum. A description and analysis of the "community of learners" approach.

[23] Schwarz, B., Dreyfus, T., & Hershkowitz, R. (2009). Transformation of Knowledge Through Classroom Interaction. Routledge.

Learning with ATLAS@CERN

Christine Kourkoumelis
University of Athens, Physics Department,
Panepistimioupoli, Ilissia 15771,Greece
hkourkou@phys.uoa.gr

Abstract

The «Learning with ATLAS@CERN» LLP project aims to demonstrate an innovative pedagogical approach which involves students, teachers and the wider public in extended episodes of playful science learning. Learning with ATLAS@CERN basic philosophy is that the learning of science is a process of creating knowledge by learners. Based on the effective use of ICT tools (virtual environments, visualization technologies, 2D and 3D animations of aesthetic quality, simulation interactive games) the project aims to offer a "feel and interact" user experience, allowing for exploratory learning "anytime, anywhere".

In this framework the consortium has developed several interactive event analysis packages with which the students or the teachers can have a pictorial visualization of the reconstructed ATLAS events and at the same time "study" or as we say "analyse" them. One of these packages-stored in the toolbox of the Learning with ATLAS@CERN portal-the HYPATIA event analysis tool, will be demonstrated on line.

Keywords

CERN, ATLAS, Public Outreach, schools, science centers

1. Introduction

The Learning with ATLAS@CERN project [1] is part of the EC Education and Culture DG Life Long Learning, two Year long (November 2008-November 2010) program. It is based on ATLAS [2]-[3], the most advanced technologically and research-wise particle experiment at the LHC [4], the world's most powerful particle accelerator located at the European Particle Research Centre (CERN) [5]. The project aims to use effectively the ICT tools, to create a pleasant learning environment and at the same time give the opportunity to the school and university students, to their teachers and the public to actively participate to the most recent and exciting research happening in the world!!

2. Project Objectives

The project's main objectives were:

- **To develop a pedagogical framework that attempted to blend informal and formal learning and to situate learning in real-world contexts.** The project developed a new science learning scheme for all by introducing a technologically advanced approach for learning by connecting a wide range of learning environments (schools, universities, science centers, and research institutions). In this way it extended the "dialogue" between citizens and scientists, schools, research organizations and science centres, promoted scientific culture in society and helped citizens to acquire a better understanding of the role of science and technology in society.

- **To develop advanced pedagogical scenarios that are shaped around a mission guided by a general scientific question.** During a Learning with ATLAS@CERN-mission, learners performed several types of learning actions that can be characterized as productive (experiment, game, share, explain, design, etc.), they encountered multiple resources, they collaborated with varying coalitions of peers, and they used changing constellations of tools and scaffolds (e.g., to design a plan, to state a hypothesis etc.). Conceptual scaffolding was extended through communication tools in the form of leading questions that set a context for the learners. Fulfilling a Learning with ATLAS@CERN mission required a combination of knowledge from different domains (e.g., physics, biology, engineering and/or social sciences).
- **To develop and evaluate a web based environment, the Learning with ATLAS@CERN Education and Outreach portal, facilitates the implementation of the pedagogical scenarios.** The system offers access to unique educational, scientific and data analysis tools and on-line materials for science education and communication and provides learners with authentic scientific and technological missions and engages them in true investigative and constructive activities. An advanced search mechanism has been developed to increase the usability of the extended digital content that was integrated to the platform. The search mechanism supports the different categories of users of the system. Specific profiles and vocabularies (e.g. connected with the school curriculum) were developed to support the retrieval of the educational content.
- **To pilot and to demonstrate the Learning with ATLAS@CERN approach in schools, universities and science centers in Greece, Finland, Sweden, Austria, UK and at CERN.** Throughout the life cycle of the project a series of user-centred learning activities (demonstrations, workshops, info days) were organized in schools, universities and science centers in the participating countries.
- **To create virtual learning communities of educators, learners and researchers and involve them in extended episodes of playful learning.** The project involves educators, learners and researchers in collaborative learning activities. Being part of a professional network encourages interaction and provides them with opportunities to enrich their practices and professional context through cooperation within and between schools, universities, science centres and frontier research institutions, collaborative reflection, development and evaluation of instruction, exchange of ideas, materials and experiences, quality development, cooperation between teachers, students and researchers and support and stimulation from research.
- **To perform an extended validation study of the Learning with ATLAS@CERN approach.** The validation work aimed a) to adapt a tried and tested methodology to validate products and services of the Learning with ATLAS@CERN project and b) to implement the validation procedure in situ in a pan-European setting.
- **To design and implement a systematic dissemination and exploitation strategy that contributed to the effective communication of the project's results and outcomes.** In this framework the aim of the consortium was to constitute a common set of guidelines and recommendations on

how scientific work can be used to provide an engaging educational experience through the exploration of "real science". In this way the Learning with ATLAS@CERN added its contribution in better understanding science and the role that it plays in society.

3. Project Organization

The work in the following seven workpackages of the Learning with ATLAS@CERN project was organized around the above aims. In parenthesis follows the leader of each workpackage.

1. Management and Scientific Coordination (University of Athens)
2. Pedagogical Design and Learning with ATLAS@CERN Missions Development (University of Birmingham)
3. Learning with ATLAS@CERN Education and Outreach Portal (University of Athens)
4. Implementation & Validation (Ellinogermaniki Agogi - GR)
5. Evaluation & Quality Assurance (University of Bayreuth)
6. Dissemination (University of Stockholm)
7. Exploitation (Austrian Ministry of Education)

4. Description of the pedagogical approach and missions

To understand the role of science people need to be educated to be critical consumers of scientific knowledge. Improving the public's ability to engage with such socio-scientific issues requires, therefore, not only knowledge of the content of science but also knowledge of "how science works". The project proposes a reversal of science teaching pedagogy from mainly deductive to inquiry-based approach that provides the means to increase interest in science.

This approach emphasizes curiosity and observations followed by problem solving and experimentation in both real and virtual settings. Through the use of critical thinking and reflection, users of the Learning with ATLAS@CERN educational environment will be able to make sense out of gathered evidence based on the most recent developments of science. Moreover, such an approach is perfectly adapted to the young audiences. This is a key advantage as starting science education at this age allows making the best use of this "curiosity golden age". In addition it will provide learners with opportunities to develop a large range of complementary skills such as working in groups, written and verbal expression, experience of open-ended problems solving and other cross -disciplinary abilities.

These pedagogical concepts and learning practices are addressed by implementing a set of missions (learning scenarios) tailored to the needs of the diverse groups of learners, employing advanced and interactive visualization technologies and also personalized ubiquitous learning paradigms in order to enhance the effectiveness and quality of the learning process. In the framework of these missions, learners are able to use a series of educational analysis tools that allow them to manipulate the most recent LHC data and make their own discoveries.

The development of the pedagogical approach and the learning missions was based on the adoption of a user-centred approach. The assessment of the missions included extended cycles of user centred work in schools, universities, science centres. User communities continuously gave feedback to the project team about their experiences gained in the trials. This not only increased the motivation of the users, and gave weight to their practical experiences, but also provided the necessary cross-links between theory and practice. Upon suggestions of the users, the project team performed the necessary adjustments to the approach (Fig. 1).

Figure 1. *The adaptability of the project's repository on the actual learning situation, using tools and scaffolds.*

As Learning with ATLAS@CERN was a small scale pilot project the work of the consortium focused on the development of a small series of missions that was be deployed in different environments across Europe, through the web (mainly) but also in the framework of the Masteclasses [6] (2009, 2010).

These specially designed missions/lesson plans are all stored in the Learning with ATLAS@ CERN portal [7] under the "repository tab" and in the part described as "learning missions" (Fig. 2).

Figure 2. *The Learning with ATLAS@CERN portal Repository page showing the missions and the educational content.*

5. Learning with ATLAS@CERN portal

The Learning with ATLAS portal contains much more information and tools. Under the repository tab, the part called "educational content", contains games and other teacher resources. (e.g. professional development materials, lesson plans, projects and activities), student-centred materials (e.g. data library, communication area, student's magazines), applications for educational projects and collaborative activities. Most of these resources already exist in the framework of the project the consortium proposes value-added services to increase the utility of existing programs through integration, coordination and where appropriate, archiving.

The Learning with ATLAS@CERN Tool-Box tab which is also a part of the portal contains educational materials and information, such as access to data and interactive analysis tools (e.g. AMELIA a 3D and HYPATIA [8], MINERVA [9] 2D respectively event displays of the ATLAS events) allow users to explore that ATLAS experiment at CERN in an intuitive way, which is much friendlier to the public.

An effective training is being offered to the users of the portal. A full set of training materials and guides of implementation is being created, covering the needs of school and university teachers as well as science museum staff. The training material consists of both printed guides and presentations for the seminar as well as online material and tutorials for use through the web service. The training includes workshops, demonstrations during teachers training activities conferences and a series of on-line seminars through the Internet.

6. An example of a mission: The HYPATIA tool

HYPATIA (the Hybrid Pupil's Analysis Tool for Interactions in ATLAS) [10] framework is designed to enable high school students and their teachers, as well as university students, to study elementary particles and their interactions, obtaining a better understanding of the interactions between the constituents

of matter by working on the most advanced visualization techniques used by modern particle physics.

This is provided by visualization of particle collisions detected by the ATLAS experiment. At the same time, HYPATIA provides access to relevant scientific analysis tools, inspiring students to become researches and introduces them to the environment of large scale international collaborations. Using the ATLANTIS event display [11] library,

HYPATIA framework (Fig. 3) enables a student to study products of the LHC proton beams collision products in the ATLAS detector. One collision product registered by the detector is called an event. In the HYPATIA framework it is possible to analyze real events registered directly by the ATLAS detector, as well as, events produced by numerous Monte Carlo generators and simulations of the ATLAS detector.

Within the framework students can accomplish various types of projects:

- Select interesting events from different event streams;
- Display all (or selected) events one at a time;
- Interact with and manipulate the event displays;
- Study the traces of the particles in different parts of the ATLAS detectors;
- Look at reconstructed particle tracks, their properties, and analyze them;
- Discover new particles by reconstructing them from their decay products;
- Summarize the results in a presentation (histogram), which contains substantial event samples;

Figure 3. *Four windows of the HYPATIA analysis tool*

In order to enable students and their teachers to accomplish various educational projects, the HYPATIA framework provides the following components:

- Necessary documentation with the background scientific information and links to further references;
- Analysis tool for the investigation and visualization of collision products;

- Collection of event files for the analysis;
- Set of exercises and assignments;

All these components of HYPATIA framework are made available at the HYPATIA web page.

Within the Learning with ATLAS@CERN project , the partners have developed several learning missions involving HYPATIA. One of them, used in the University of Athens Nuclear Physics laboratory is called "Identifying LHC events with HYPATIA" and has three parts, according to which the students :

- Study (and recognize) the traces of different leptons in different parts of the detector
- "Discover" Z particles reconstructing them from their decay products and distinguish them from the background.
- "Discover" a Higgs particle among a few simulated events.

The above scenario was first launched during the academic year 2009-2010 for 25 undergraduate students, following the elementary particle specialization, in two week sessions of three hours each. Questionnaires were distributed at the end and the scenario was graded by the student with 3.8/5. The students jugged that its most prominent feature was the possibility to work with very modern detectors. Next year the scenario will be enriched with real data from the LHC.

7. Learning with ATLAS@CERN Guide of Good Practice

Finally the Learning with ATLAS@CERN consortium developed a structured set of guidelines and recommendations on how effective collaboration between researchers and the educational sector (formal and informal) could create valuable and meaningful learning experiences for all, fostering exploration, discovery, curiosity and collaboration. As a final step, the whole process will be documented in the main outcome of the project, namely the Learning with ATLAS@CERN Guide of Good Practice. The guide will emphasize on a new way of learning about science that reflects how science itself is done, on inquiry as a way of achieving knowledge and understanding about the world. It will propose new ways of interacting with scientific content and it will demonstrate the results from the extended validation effort in the participating institutions and beyond.

8. References

[1] Learning with ATLAS at CERN website http://www.learningwithatlas.eu/

[2] A Toroidal LHC ApparatuS (ATLAS), http://atlas.ch/

[3] G.Aad et al, "The ATLAS experiment at the LHC", JINST 3:S08003, 2008

[4] Large Hadron Collider (LHC), http://lhc.web.cern.ch/

[5] European Organization for Nuclear Research(CERN), http://public.web.cern.ch/

[6] International Masterclasses for High School Students http://www.physicsmasterclasses.org/

[7] Learning with ATLAS at CERN portal : http://www.learningwithatlas-portal.eu/

[8] HYPATIA website http://hypatia.phys.uoa.gr/

[9] MINERVA website http://atlas-minerva.web.cern.ch/atlas-minerva/

[10] D. Fassouliotis, C. Kourkoumelis, Z. Roupas and D.Vudragovic, "The ATLAS Student Event Challenge",CERN Note (2007), ATL-OREACH-PUB-2007-001

[11] Atlantis event display for ATLAS, http://atlantis.web.cern.ch/

Learning with ATLAS@CERN: Quality Assurance & Validation

Gabriele Froehlich & Franz X. Bogner
University of Bayreuth
gabriele.froehlich@uni-bayreuth.de, franz.bogner@uni-bayreuth.de

Abstract

Learning with ATLAS@CERN is an European educational project about LHC and the ATLAS detector at CERN. Within its framework, a self-running educational portal was established containing educational material about particle physics and masterclasses, workshops and/or other activities promoting the inquiry-based learning approach to teach particle physics.

In this present article the validation process of this project is described. The combination of web-based evaluation, based on Google Analytics, and offline evaluation, done with interviews and pen-and-paper questionnaires, was chosen for monitor this ICT-based educational project. Our results show that we reached teachers and students likewise.

Keywords

CERN, inquiry-based learning, validation.

1. Introduction

The Learning with ATLAS@CERN project is an recent innovative educational project by combining expertise from frontier scientific with educational research in both, formal and informal science learning. The project has combined different activities in the frame of an innovative pedagogical approach with the specific intent to support an effective “dialogue” between scientific research and the general public. The project specifically proposes a shift from a conventional science teaching pedagogy with its mainly deductive focus towards an inquiry-based approach with its learner-specific constructivism. The latter may provide the impetus to increase interest in science. The proposed approach emphasizes curiosity and observations which are followed by problem-solving and experimentation in both real and virtual settings.

These pedagogical concepts and learning practices could be addressed by implementing a set of missions (learning scenarios) tailored to the needs of the diverse groups of learners, by employing advanced and interactive visualization technologies and also personalized ubiquitous learning paradigms in order to enhance the effectiveness and quality of the learning process. In the framework of those missions, users may be more likely to use a series of educational analysis tools that allow them to work with scientific data and make their own discoveries. A web-based educational environment facilitated the proposed process. The Learning with ATLAS@CERN educational environment provided access to almost real-time data and interactive analysis tools, 3D and 2D animations of physical processes in a game-like approach, teacher-resources, student-centered materials, applications for educational projects and collaborative activities.

The Learning with ATLAS@CERN approach of inquiry-based learning followed a well structured concept including several steps. An inquiry-based learning scenario is performed as follows:

Phase 1: Question Eliciting Activities
Phase 2: Active Investigation
Phase 3: Creation
Phase 4: Discussion
Phase 5: Reflection

The project was implemented in schools, universities and science centers in selected countries (Greece, Sweden, Austria and UK). This present chapter specifically highlights the validation process, including the description of the validation tools (Google Analytics, online questionnaires, interviews, pen-and-paper questionnaires) and a summary of the results.

2. Scope and Methods

The validation of the Learning with ATLAS@ CERN-project splits up in an online and an offline validation process. The online validation (data from Google Analytics and online-questionnaires) focused on a user's feedback about the portal, especially concerning the scientific repository developed within the project, its educational usefulness and impact on science education. The offline validation was based on pen-and-paper questionnaires and specifically included individual interviews after participation. The following questions were addressed:

(1) What are the users' reasons for visiting the Learning with ATLAS@CERN-portal and what are their motivations to use it further on?

(2) How do users estimate the quality of the features of the Learning with ATLAS@CERN-portal and the provided educational content, and how satisfied are they?

(3) How is the users´ performance on the website and what conclusions can be drawn from it?

(4) How efficient and informative are the workshops and activities introducing the Learning with ATLAS@CERN-project?

(5) To what extend and how is modern particle physics taught in European schools and how can the Learning with ATLAS@CERN-project benefit to that?

For the qualitative monitoring, we conducted individual interviews of some workshop participants. In these interviews, we checked their experience with the Learning with ATLAS@CERN educational activities, curriculum related aspects, general impressions, etc.

For the quantitative validation, a pen-and-paper-questionnaire was applied for teachers and students participating. These questionnaires are based upon the VALNet framework [1], which was adopted in the Learning with ATLAS@CERN project to guide a reflective process of validating objects, aspects and resources of the project. VALNet follows a consistent methodology for ICT-school pilots. The methodology offers a framework for validating innovative technological products so that piloting and field testing results can be collated and analyzed systematically and disseminated widely, thus ensuring rapid impact and widespread uptake.

The VALNET validation framework provides a battery of items through which the innovation content of ICT projects, as the Learning with ATLAS@CERN project, can be analyzed. We used its specific subscale focusing pedagogical aspects concerning our portal. Furthermore, project-specific questions were included to evaluate the inquiry-based learning approach. Additionally, technological, educational and organizational aspects were monitored and some open questions were included to get more feedback of the participants`. The impact on participants' intrinsic motivation was monitored by using specific subscales of the Intrinsic Motivation Inventory [2], covering namely Interest/Enjoyment and Value/ Usefulness.

Google Analytics as an on-site web analytics tool allows a portal operator to collect visitors' data. It uses specific cookies, which facilitates to identify the visitors and thus track whether the visitor has been to the site before. This tool offers various information on visitors´ home countries, their timestamp of the current and following visits, which pages were visited, etc.

3. Results & Discussion

3.1 Web Analysis

The quantity of visitors and visits is an important indicator for the popularity of a website.

The computer, not the individual visitor, can be identified by the already mentioned cookie placed on the computer. Therefore, the actual number of visitors supposedly may score even higher in reality. The number counted by Google Analytics is the quorum.

In our data analysis, we concentrate on returning visitors. These are users who visited portal more than once. We excluded one-time visitors from analysis, because they may have hit our portal accidently. This may easily be justified by their duration spent on the portal (majority <10 s).

During the main period of data collection (1st February 2010 – 1st July 2010) 1,319 users visited the Learning with ATLAS@CERN-portal, nearly half of them were so-called returning visitors. The portal, therefore, was shown as very popular and interesting for the users; the average time visitors spent on the website was quite long: New visitors spent more than 4 minutes while returning visitors extended this duration up to 1.5. times longer compared to the average of all users (see Table 1).

	All Visitors	Returning Visitors	New Visitors
Visits	1,319	672	641
Average Time on Site [min]	05:58	07:15	04:35
Average Page Views per Visit	5.32	5.89	4.74

Table 1. *Visitors on the Learning with ATLAS@CERN-portal (01.02.2010 – 01.07.2010).*

Count of visits [times]	2	3	4	5	6	7	8	9-14	15-25	26-50	51-100	101-200	> 201
Visits that were the visitors nth visit	139	71	54	39	32	27	22	58	34	56	131	5	6
% of all visits	20.6	10.5	8.0	5.8	4.8	4.0	3.3	8.6	5.0	8.3	19.4	0.7	0.9

Table 2. *Loyalty of Learning with ATLAS@CERN-portal returning visitors from 01. February 2010 to 01. July 2010.*

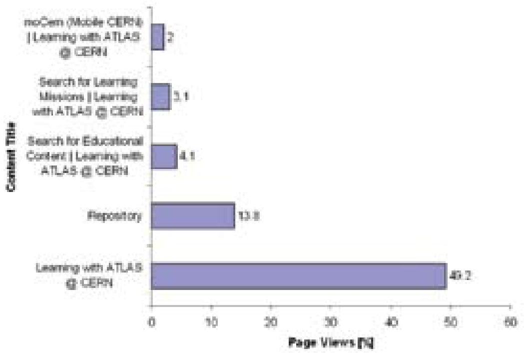


Figure 1. Overview over the most viewed contents on the Learning with ATLAS@CERN portal.

Besides the mere quantity, the quality of visits was also of specific interest. We, therefore, analyzed the average time on each page and the number of pages viewed per visit. We assumed that the longer a visit lasted and the more pages were viewed, the more extensive the visitor dealt with the portal and the higher the quality of the visit was. It takes four page views to get to the sections of the portal where visitors can contribute to the repository or download educational material or Learning with ATLAS@CERN tools. Therefore, we postulate this value as a threshold for quality visits and consider visitors with more than four page views as active users of the portal (see Table 1). To analyze the loyalty of our users, the number of visits of each user was counted (Table 2). The active community uses the portal for uploading own material, prepare specific physic courses for students, get latest information of the ATLAS project and so on. About 19 %, which is rather every fifth user of the returning visitors was visiting the portal 51 – 100times. This is an encouraging result especially when considering the limited time assigned to particle physics in European school curricula.

The web analysis also provided some deeper insights into which portal pages interested visitors most. We, therefore, analyzed the page views with regard to the page content, assuming that the more users were interested in a specific page, the more page views it would get. The most viewed page by far was the Learning with ATLAS@CERN home page (49.2 % of total page views; Fig 1). This is not surprising because every user enters the portal via this page. The pages visited after the home-page reveal the interests of the users, because now they can freely choose their way of navigating through the website

The second most interesting page was the Learning with ATLAS@CERN Repository. This page contains educational material in form of selected educational contents (photos, videos, animations, exercises, graphs and links) and of learning missions (structured lesson plans organized according to the specific pedagogical model inquiry-based learning). In this repository like it is displayed in Figure 3 also the toolbox is included. The pages containing the search tool for either educational content (4.1 %) or learning scenarios (3.1 %) also were very popular. The most positive feature, however, was the collection of the educational material about particle physics. According to these results, the visitors are using it more in that way than just uploading their own educational material.

3.2 Questionnaires

Two versions of pen-and-paper questionnaires were applied in the validation workshops and masterclasses, one for students and another one for teachers. The questions focused on the workshop/masterclass itself (organizational, pedagogical aspects), the interest in particle physics and the opinion about the Learning with ATLAS@CERN portal. The masterclass aimed at the project's dissemination, at getting the teachers motivated to upload and download educational material and at getting get the students interested in particle physics. For both target groups, the masterclasses started with theoretical background information about the project, ATLAS and particle physics. At the end of the activity, the participants had to complete the questionnaires.

All in all, teachers participating in this survey were quite familiar with ICT and had a positive view of new technologies and innovative educational methods. More than 90 % of the reviewed teachers had the opinion that the ATLAS experiment is a perfect way to teach basic physical ideas and the most recent developments in this specific scientific field. Nearly the same percentage of teachers saw the need to overcome with the old-fashioned curricula in physics and that it is more interesting for the students to learn about modern physics. By doing this, probably one may overcome the lack of interest many students have in science. 65.4 % of the workshop participants stated that their teaching practice might change after the workshop. This is remarkable with respect to the fact that most of the teachers usually have a broad repertoire of teaching materials available and using educational portals might be just an enrichment of their existing materials. The yet high willingness to change established teaching practices leads to the conclusion that ICT-based technologies fill a big gap in the needs and wants of teachers and that our described portal reaches to satisfy these. Furthermore, the teachers might increase their interest in other educational portals after they worked with our portal. In the workshops they got to know the advantages these kinds of portals can have for them: very easy access to educational material, exchange with other teachers from all over the world and providing own learning material to others. Another good result is that even they got to know the process to upload learning scenarios, which is rather time consuming to fill in all the metadata, 61.6 % of the teachers are motivated to upload some more. This is a very good outcome, because the way our portal is organized, an active community is essential for the portal's success and especially to keep it going on after a project's end.

The difficulty of tasks is an impact factor for students´ motivation and interest [3]: 55.5 % of the students considered the exercises not difficult. Every third student was undecided. This fits to our requirements in this way, that the students got so much information in only a couple of hours that the exercises shouldn't overstrain them. If students get over-challenged their motivation would fade away to learn or participate actively in the workshop. Nearly every third of the students totally agreed to the circumstance that the activity has increased their interest in physics.

The result of the students´ questionnaires showed that they are very interested in the topic itself and that they would like to do more modern physics at schools. This would be definitely a considerable way to increase students' interest in science.

3.3 Interviews

The interview questions covered the participants´ interest and their knowledge in modern physics, especially ATLAS, and their opinion regarding the workshop in terms of organizational, technical and educational aspects. There were also some questions about their interest in the portal, as it was introduced in the masterclass. The students and especially the teachers were very interested in particle physics, although at school the curricula do not foresee to intensify the topic.

Our survey showed that people are interested in what is going on at CERN and what the ATLAS experiment is all about. Even, if you use newspapers and internet as information sources there is still mystery about the experiments in the public opinion.

Some students mentioned the movie "Angels & Demons", which was shown in the cinemas in 2009, in which CERN is part of the setting. It is a science fiction thriller about conspiracies of secret societies. So, the image of CERN and the ATLAS experiment as a secret and potentially dangerous experiment is nearly in everybody’s mind. Therefore, an urgent need is given to adjust this opinion. This was one of our project’s aims and the statements of the interviewees supported the need for that. All in all, the students and teachers were satisfied with the contents of the masterclass and in their subjective opinion they had learned sufficiently.

3.4. Summary

The combination of web-based quantitative evaluation and qualitative validation by means of paper-and-pencil-questionnaires and interviews is a proper way to get an overall impression of the success of an educational portal like the Learning with ATLAS@CERN portal.

The correlation between activities and the interest in the portal can be supported by comparison of the visitor data provided by Google Analytics and the dates of the workshops. This supports the impression that the interest was aroused by the project activities and we can furthermore assume that the participants told colleagues about the project and/or portal. This specific argument is also supported by the results of the validation. According to the paper-and-pencil questionnaires, 96.2 % of the teachers, who are the main target group of the portal, stated their willingness to recommend the project to their colleagues.

The application of web-based analysis with Google Analytics has proven to be an adequate tool to validate a portal.

There is an established community using the features of the portal regularly. The ratio of returning visitors in the data collection period with nearly 51 % was quite high. This was also valid for their average time on site (07.15 minutes) and the loyalty of visitors. About 19 % of the returning visitors contacted the portal 51-100 times, which might provide itself as a valuable indicator for an active community. Our presented portal, thus, became an integral part of teachers´ instructional preparation with the search function being the most popular feature. This is confirmed by the high motivation to use our portal further on as revealed by quantitative analysis.

According to teachers´ answers in interviews and questionnaires, the biggest problem they see for the success of the Learning with ATLAS@CERN portal in the scarce time which curricula foresee to teach modern or particle physics. Due to that circumstance they raised considerable doubts about a regular usage of our offered learning scenarios and to have the time and motivation to prepare a learning scenario. Especially among the teachers, there were more than 90 % convinced that the ATLAS experiment is a perfect way to teach basic physical ideas as well as the latest developments in physical research. Therefore, there is a prospect of success that teachers will still use our portal in the future. By recommending it to their colleagues, the portal might become a self-running system where a wide range of information and educational material about particle physics is collected.

We assume the teachers as the main target group of our portal. Nevertheless, it is also interesting to see what students think about the ATLAS experiment, particle physics, the masterclasses, and the use of ICT at schools. According to that, we developed questionnaires for students, which were filled in during the activities they participated in our project.

Interestingly, more than 83 % of the students said that they have a non-scientific subject as favorite subjects, but even though, most of them enjoyed the activity day very much so that more than three quarters of the students would recommend the activity to other students. All in all, the students rated the workshops and/or masterclasses as very good and considered the exercises as interesting. This was not only because of the content. The students were all very open and favorable to the inquiry-based learning approach. It was a motivating issue for them to learn about an actual and discussed topic, like the CERN project and to get an idea how the "real" researcher work at CERN.

The results of the validation work of the Learning with ATLAS@CERN-project are encouraging. The main objectives of the project were:

1. Establishing an self-running educational portal containing educational material about particle physics,
2. Doing masterclasses, workshops and/or other activities promoting the inquiry-based learning approach in the framework of particle physics.

This combination of objectives in this project is according to our data a very good way of complementing each other and to achieve our goals. This concept seems to be appropriate to increase the interest of teachers in innovative teaching methods and the interest of students in science, particular modern physics.

6. References

[1] MENON Network, Final VALNet Validation Framework, Deliverable Code: M2.2T12:D2.1, Project Number: IST1999-14025 (VALNet) http://www.know-2.org/k2docs/markswabey_20-02-03_10-43-41.pdf [visited 20-Aug-2010]

[2] Deci EL & Ryan RM: Intrinsic Motivation Inventory http://www.psych.rochester.edu/SDT/measures/IMI_description.php [visited 20-08-2010]

[3] Paas F, Renkl A, Sweller J. Cognitive load theory and instructional design: Recent developments. Educational Psychologist 2003; 38(1):1-4.

International Masterclasses in Physics

Kenneth Cecire
University of Notre Dame, Department of Physics
225 Nieuwland Science Hall
Notre Dame, Indiana 46556 USA
kcecire@nd.edu

Abstract

The particle physics masterclasses, coordinated by the European Particle Physics Outreach Group under the direction of Michael Kobel of the Technical University of Dresden, give secondary school students the chance to work collaboratively with particle physics data and analyze real data with physicists as their mentors. Students compare the results of their analyses internationally via videoconferences moderated from CERN and, more recently, Fermilab. Evaluations have shown that students increase their interest in and understanding of particle physics in the masterclasses; furthermore, the masterclasses are popular with students, teachers, and the physicists themselves. As a result, the program has steadily grown in terms of numbers of institutes offering the masterclass, countries participating, and total number of students. The masterclasses offer a possible model for physics outreach and improved student learning of science.

Keywords

EPPOG, Masterclass, Physics Education, Particle Physics

1. What is a masterclass in physics?

A masterclass is a familiar part of education in the arts. For example, a cello student might learn a piece of music, practice and prepare it, and then spend a day with a recognized expert—a master—who helps him/her to improve performance of the piece. In the process, the student learns not only the fine points of the piece but also much about the cello and the structure of music. He or she becomes a better musician in the process.

In the physics masterclass, the process is similar but more compressed. High school physics students come together to a university or laboratory—a physics masterclass institute—and learn basics of particle physics and how to understand a specific set of data; they then analyze that data under the mentorship of recognized experts—this time particle physicists. The result is similar to that in an arts masterclass: students learn not only something about the topic in particle physics but about the process of physics research and the application of fundamental physics principles. [1]

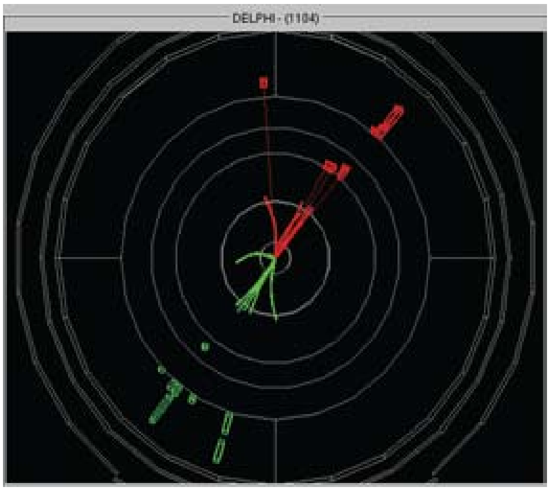


Figure 1. *Display of a Z-decay event from the DELPHI detector in LEP of the sort that students analyze. This event is a candidate for a Zo decaying into jets of hadrons.*

The data analysis exercise, which has been the primary vehicle for physics masterclasses since 2005, is the analysis of event displays from the Large Electron-Positron (LEP) collider at CERN. Each display shows the products of a real decay of a Z-boson. There are 1000 such events in the exercise. Students work in pairs; each pair of students will analyze some number of events so that the whole group at the masterclass institute covers all 1000. Their goal is to determine the "branching ratios" of the Z0: the percent of decays that result in four possible sets of product particles: electrons, muons, taus, or quarks. The quark decays are seen as jets of hadrons and students can also determine the ratio of three-jet to two-jet events to determine the strength of the strong nuclear force relative to other fundamental forces. [2]

Students learn more about elementary particle physics than they would in their high school classes; they also learn about LEP and collider detectors. Generally, the Large Hadron Collider (LHC) is introduced and compared with LEP. However, as they analyze the event displays, students put other fundamental physics concepts to use, including, but not limited to, conservation of momentum, conservation of mass-energy, and the interactions of charged particles, thus sharpening their understanding of physics generally. They also are exposed to uncertainty in analysis; because the data is from real events, there are all of the anomalies and questionable results that come from limitations on human measurements and the vagaries of nature. Finally, they begin to see data as physicists see data: not as received information but as something to be probed, questioned, argued over, and analyzed in order to attempt to reach a consensus on the meaning. [3]

2. History and scope of the program

The physics masterclasses started in 1997 in the UK based on an idea by Ken Long of Imperial College and Roger Barlow of the University of Manchester. [4] The first masterclasses were conducted in 1997 using the Identifying Events package for the OPAL detector of LEP and the Lancaster Particle Physics package. There were seven to eight original masterclass institutes. Contributors included Long and Barlow as well as Terry Wyatt at the University of Manchester and Peter Watkins at the University of Birmingham. The program continued and grew in the UK. [5] In 2005, the European Particle Physics Outreach Group adopted the masterclasses as a Europe-wide effort; Erik Johannson of the University of Stockholm contributed a JAVA-based event display of Z-decay events from the DELPHI detector in LEP, which made for a very user-friendly and interesting interface for the students. Michael Kobel of the Technical University of Dresden took charge of organizing the masterclasses. In 2005, about 3000 students from 18 countries participated; the program has grown steadily since then. [6]

In 2006, the United States began to participate in the masterclasses with six students from the Brookhaven QuarkNet center. [7] Working collaboratively with EPPOG, by 2009, the U.S. had its own program with videoconferences hosted from Fermilab.

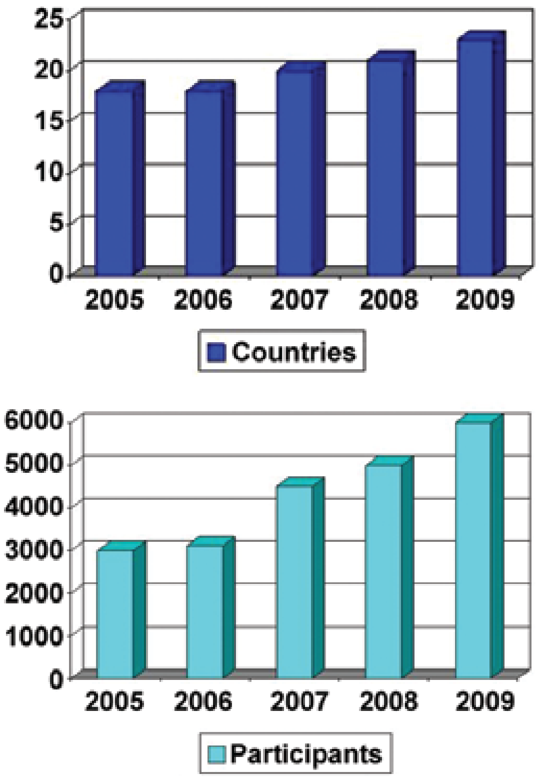


Figure 2. Growth in the EPPOG masterclasses from 2005 to 2009. [8]

In addition to European countries and the U.S., masterclasses have extended to Brazil, South Africa, and, most recently, Japan. By 2010, there were approximately 6500 students participating from 24 nations over a 17 day period in February and March. They met in 107 masterclass institutes around the world.

There are other particle physics masterclasses which occur every year that are not connected to the main CERN and Fermilab videoconferences. For example, most of the masterclasses in the UK currently use simulated data from the ATLAS detector in the LHC and run on a separate schedule. [9]

3. Results from evaluations

There are three sets of evaluation results that are discussed here. First, there is an independent evaluation performed in Europe, published in Physics Education in 2007. [10] The second is an evaluation conducted by Konrad Jende, a candidate for a Ph.D. in Physics Didactics at the Technical University of Dresden conducted in 2010, also in Europe. [11] The third is an ongoing evaluation of U.S. Masterclass students begun in 2009. [12]

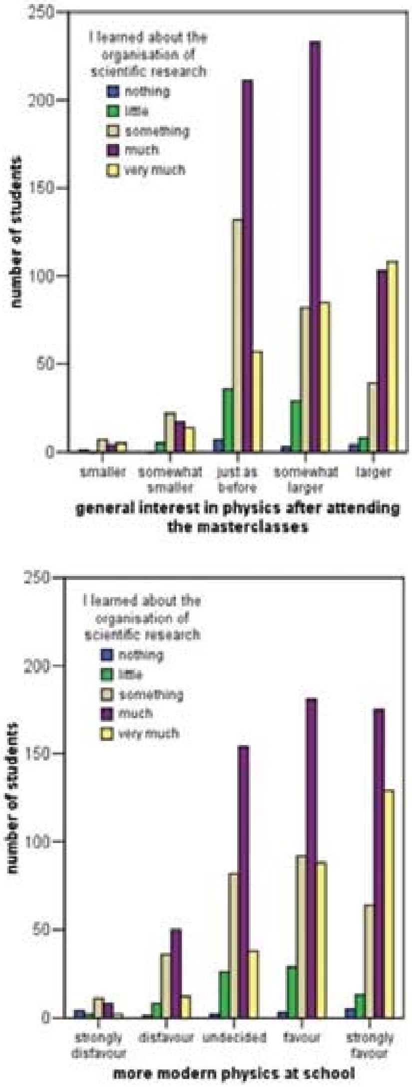


Figure 3. Graphs from the 2007 paper showing that students reported learning more about particle physics, gaining enthusiasm, and learning about how scientific research is performed. [13]

The original evaluation and the 2009 European evaluation were based on very similar self-reported surveys of students immediately after their masterclass experiences. Students were asked about their experience and how it affected their knowledge of and attitudes toward particle and modern physics. The results in both cases showed that students were generally enthusiastic about the masterclass, learned something, and gained a greater appreciation for modern physics.

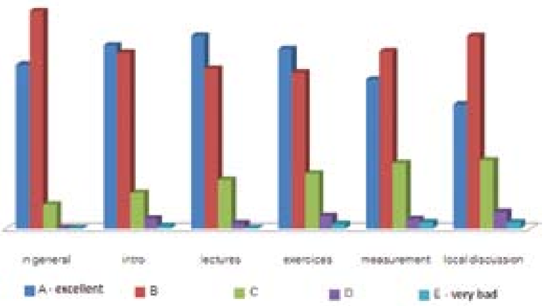
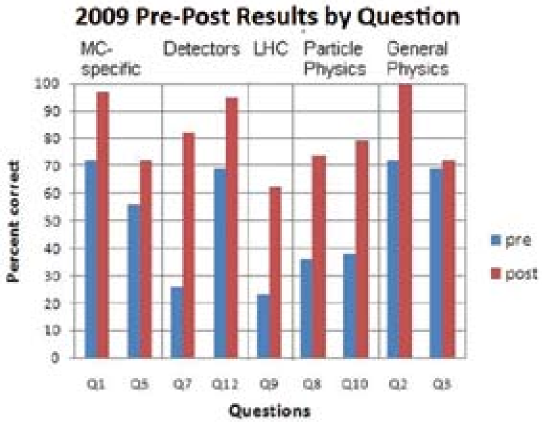


Figure 4. The 2009 survey of 431 students in 11 countries shows generally high ratings for all of the main aspects of the masterclass. [14]

In the U.S. evaluation, Quarknet staff collected data under the directions of MJ Young & Associates, a firm that specializes in education program evaluation; Jean Young analyzed the results. Students filled in a survey based on the European surveys and took quizzes to track main concept learning. Where U.S. students answered survey questions identical with European survey questions, results were nearly identical. Since the U.S. program included classroom preparation before the masterclass, students were given a pre-program, pre-preparation quiz, a middle quiz between preparation and the masterclass, and a post-program quiz several days after the masterclass, allowing staff to assess student learning at each stage. As of the writing of this article, the most recent results that have been analyzed are survey results for 2010 and quiz results for 2009.



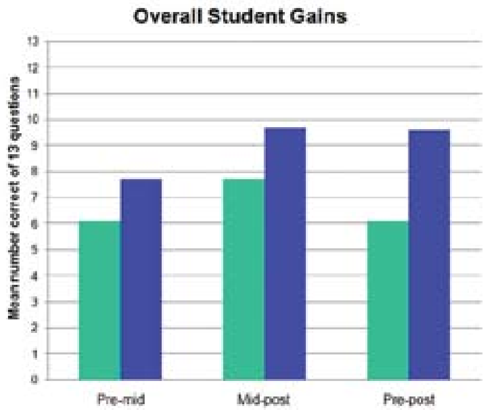


Figure 5. The U.S. pre-, mid-, and post-quizzes from 2009 show solid student gains in learning about key aspects of particle physics. [15]

Some note should be taken of who the students were. Worldwide, they were advanced students in their two final years of high school who had studied and/or were studying physics. They mostly attended the masterclasses out of interest in physics; thus, the students coming to the masterclasses were already disposed toward the subject and yet increased both their enthusiasm and knowledge.

4. Future of the program

The international masterclasses are expected to continue to grow in numbers of students, institutes, and countries. This is the natural result of success seen in the program and interest by students, teachers, and the particle physics community.

That stated, the program is at an exciting inflection point with the operation of the Large Hadron Collider at CERN. In the previous masterclasses, students were exposed to LEP data but pointed over the horizon at the LHC and the exciting results that are expected. In 2010, the LHC is producing data. Thus, the 2011 masterclasses are projected to use event displays and data from the ATLAS and CMS detectors in the LHC.

There are two data analysis exercises anticipated: analysis of W-boson lepton decays to reveal the charge structure of the proton and analysis of Z-boson lepton decays to probe the balance of lepton flavors. In both cases, students will need to separate out background events and are likely see simulated events in which unusual decays are revealed. Beyond 2011, other exercises may be added. [16]

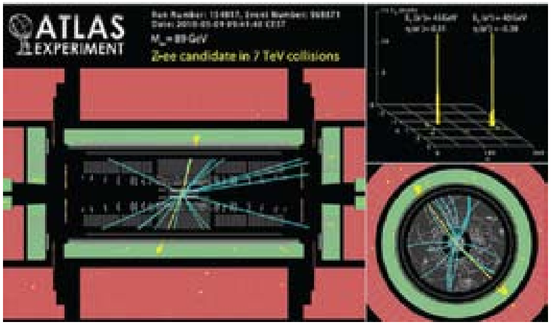


Figure 6. *A candidate event for the decay of the Z-boson into an electron-positron pair in ATLAS. This is one of the kinds of events that students will analyze in the 2010 masterclasses and beyond. [17]*

5. Masterclasses as a model in physics education

The future of the masterclasses can and should include the creation of new exercises to elucidate other branches of cutting-edge physics. The masterclass approach works well to engage students, increase their enthusiasm, and help them learn about physics in ways they would not in the typical high school classroom.

Within nuclear and particle physics, it is not difficult to see how the masterclass model can be adapted. The largest task would be to choose a set of events and an appropriate event viewer. This would have to be a student-friendly event display that shows some consistent set of data. For example, a masterclass could be created for a B-factory experiment such as BELLE: one could imagine a set of simple event files for B-meson decays, which would allow students to measure displaced vertices to determine lifetime.

In the larger world of physics, more adaptation would be needed; however, the core elements: basic instruction on the background physics and how to analyze data, data reduction and analysis by students with scientist mentors, and a community meeting to discuss results.

6. Acknowledgements

The author would like to thank Peter Watkins of the University of Birmingham for useful historical information and Uta Bilow of the Technical University of Dresden for program information. Thanks go to Jean Young of MJ Young & Associates and to Konrad Jende of the Technical University of Dresden for evaluation results. Special thanks to Michael Kobel of the Technical University of Dresden for all of the above: as program leader, his overall knowledge is particularly vital. Great thanks also to Marjorie Bardeen of Fermilab for careful edits and useful notes on the U.S. program and to LaMargo Gill of Fermilab for editing. Finally, thanks to the QuarkNet teachers who keep me grounded.

7. References (and Notes)

[1] QuarkNet VLHC Fellows. U.S. Masterclass Orientation Guide, 2010; http://quarknet.us/library/upload/c/ce/MCOrientation2010.ppt

[2] Hands-on-CERN; http://www.physicsmasterclasses.org/exercises/hands-on-cern/

[3] Kobel, Michael. Hands-on Particle Physics (presentation). Plenary ECFA meeting, CERN, 26 October 2009.

[4] Morrison, Andrew. Researchers help motivate high school students. Physics Education; 36(1): 10.1088/0031-9120/36/1/801.

[5] Watkins, Peter. Personal communication.

[6] Bilow, Uta. Hands-on Particle Physics (presentation). Incontri di Fisica, INFN-LNF, 9 October 2009.

[7] Lee, Jennifer Lauren. Looking for Leptons in All the Right Places. Symmetry; 3(6); http://www.symmetrymagazine.org/cms/?pid=1000362

[8] Kobel. 2009.

[9] Cecire, Kenneth. The Masterclass in the U.S., 2010 (presentation). EPPOG spring meeting, 16 April 2010.

[10] Johansson, K. E., Kobel, M., Hillebrandt, D., Engeln, K., and Euler, M. European Particle Physics Masterclasses make Students Scientists for a Day. Physics Education; 42(2007); 636-644.

[11] Jende, Konrad. Evaluation of the 6th International Particle Physics Masterclasses 2010 (presentation). EPPOG spring meeting, 16 April 2010.

[12] Cecire. 2010.

[13] Kobel. 2009.

[14] Jende. 2010.

[15] Cecire. 2010.

[16] Kobel, Michael. First ideas of physics concepts for the LHC masterclass measurements (presentation). EPPOG spring meeting, 16 April 2010.

[17] ATLAS Collaboration. http://atlas.ch

An exercise based on visual identification of strange particles; a proposal by ALICE for the Masterclasses

Pawel Rafal Debski
Warsaw University of Technology, Warsaw, Poland
pawel.rafal.debski@cern.ch

Panagiota Foka
GSI Helmholzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
yiota.foka@cern.ch

Despina Hatzifotiadou
INFN and Dipartimento di Fisica, Università di Bologna, Bologna, Italy
despina.hatzifotiadou@cern.ch

Boris Hippolyte and Antonin Maire
Institut Pluridisciplinaire Hubert Curien (IPHC), Strasbourg, France
boris.hippolyte@cern.ch and antonin.maire@cern.ch

Matevz Tadel
PH Department, CERN, 1211 Geneva 23, Switzerland
matevz.tadel@cern.ch

Abstract

The European Masterclasses, organised by EPPOG (the European Particle Physics Outreach Group) since 2005, have been using LEP data (mainly Z0 and W decays). Now that the LHC is up and running, EPPOG intends to include exercises based on LHC data in the Masterclasses. The ALICE experiment, designed to study heavy ion collisions, has developed an exercise based on the visual identification of strange particles.

The proposed exercise consists of a search for strange particles, based on V0-decays such as $K^0s \rightarrow \pi^+\pi^-$, $\Lambda \rightarrow p + \pi^-$ *and cascades, such as* $\Xi^- \rightarrow \Lambda + \pi^-$ ($\Lambda \rightarrow p + \pi^-$). *The proposed tool is an implementation of the visual V0 and cascade finder, used by the standard ALICE event display, in the ROOT framework; in this way it can easily be ported to any computer without requiring the installation of the whole ALICE software. The identification of the strange particles will be based on the topology of their decay combined with the identification of the decay products; the information from the tracks will be used to calculate the invariant mass of the decaying particle, as an additional confirmation of the particle species. Thus the*

pupils will be introduced to the concept of invariant mass. This can be complemented by a discussion on particle identification methods and techniques, which is one of the strong points of ALICE.

Keywords

ALICE experiment, cascade decays, strange particles, V0 decays.

1. Introduction

The European particle physics Masterclasses are organised by EPPOG (the European Particle Physics Outreach Group) since 2005. The aim is to introduce high school pupils to particle physics and to offer them hands-on experience by giving them experimental data to analyse using real analysis tools. The project has been very successful. It is organised every year over a period of some weeks during February and March in a number of European cities. Some thousands of pupils take part every year and the demand for participation keeps increasing. Lately some American and Asian schools have also participated in the Masterclasses. Until now the Masterclasses have been using data from LEP, the Large Electron Positron Collider, mainly Z0 and W decays. Recently some exercises with simulated data from the LHC, the Large Hadron Collider, have been added. Now that the LHC is up and running, EPPOG intends to include exercises based on LHC data in the Masterclasses.

2. The basic idea of the proposed exercise

One of the characteristics of events from proton-proton and lead-lead collisions at LHC is their complexity, as compared to the clean signatures from electron-positron collisions. Fig. 1 shows such a clean signature from e+e- collisions at LEP (from the OPAL experiment), used for the existing European Masterclasses [1]; fig. 2 shows a typical proton-proton collision at LHC from the ALICE experiment.

Figure 1. *Example of $e^+e^- \rightarrow \mu^+\mu^-$ event from the OPAL experiment at LEP.*

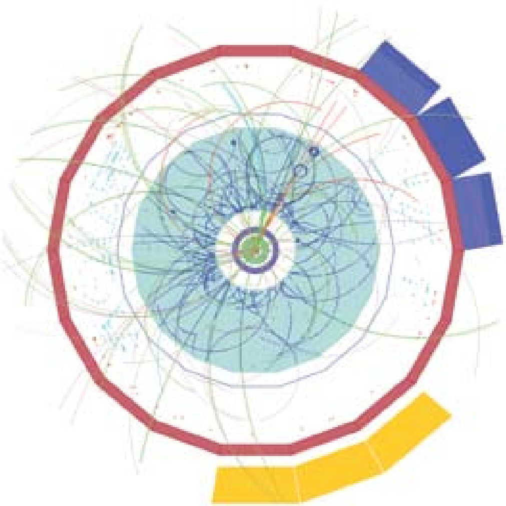


Figure 2. *Example of an event from the ALICE experiment at LHC (7 TeV proton-proton collision).*

This complexity makes it difficult to propose an exercise which can make some physics measurement based on a relatively clean signal. The ALICE heavy ion experiment at LHC [2] proposes an exercise consisting of a search for strange particles; this will be based on the visual identification of their V0 and cascade decays. An example of an event with such a decay can be seen in Fig. 3.

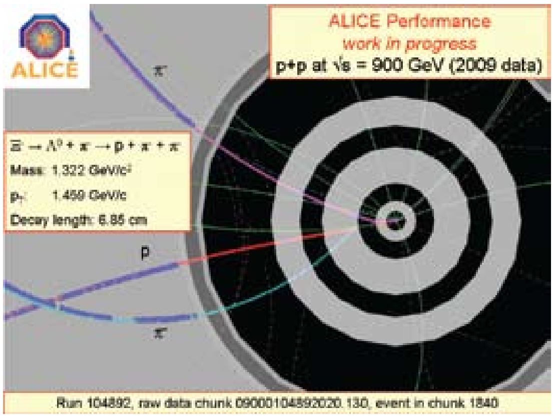


Figure 3. *Example of a cascade decay of a Ξ^-.*

3. The physics motivation

One of the goals of ALICE is the search for quark gluon plasma (QGP), a state of matter that existed for a brief fraction of a second after the Big Bang; this is expected to be reproduced at the extreme temperatures and densities resulting from collisions of lead ions at the LHC. One of the signatures for the creation of this primordial state of matter, the QGP, is the enhancement of strangeness; this exercise, consisting of a search for strange particles, will give the opportunity for an introduction to heavy ion physics and QGP and a discussion of the experimental signatures.

4. The tools

A visual V0 and cascade finder has been implemented inside ALIEVE, the standard ALICE event display [3]. In principle ALIEVE could be used for the exercise, in which case no additional software development would be necessary; however this would require the installation of the whole ALICE analysis software on the computers to be used for the masterclass exercise and make the operation difficult. To get around this problem, the visual V0 (and cascade) finder routines were implemented in the ROOT framework [4]; in this way the software needed for the exercise can easily be ported to any computer which supports ROOT, and is independent of the ALICE software.

Figure 4. *Startup window of the masterclass exercise.*

Starting the exercise in the ROOT frame (root masterclass.C) the pupils are presented with a small window, as shown in Fig. 4. This offers the choice between demonstration mode (examples of K^0s, Λ and Ξ^- decays), student mode for the event analysis and teacher mode for the collection and merging of the results.

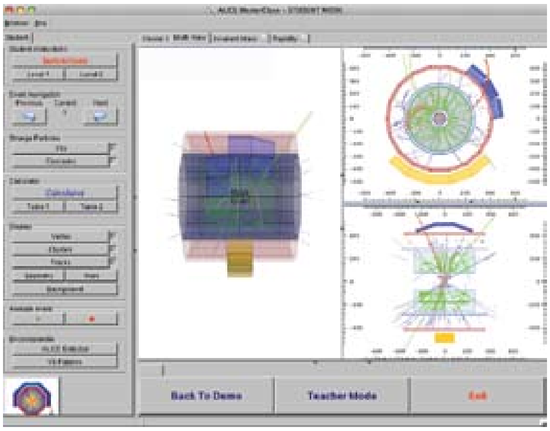


Figure 5. *Analysis window for the masterclass exercise, with menu and three views of the detector.*

The choice of "student mode" for the event analysis and visual search for V0s opens a window similar to the ALIEVE event display environment, shown in Fig. 5. The column on the left offers a number of options : Instructions, Event Navigation, V0 and cascade finder, calculator, selection of what is displayed (tracks, detector geometry, ...). In addition there is event animation and "Encyclopedia", with a brief description of the ALICE detector and its main components plus the V0 decay patterns.

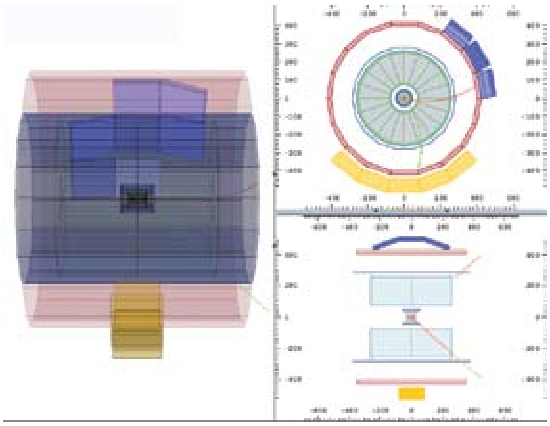


Figure 6. *Three views of the ALICE detector showing only the tracks from a V0 decay (the rest of the tracks of the event are not displayed) .*

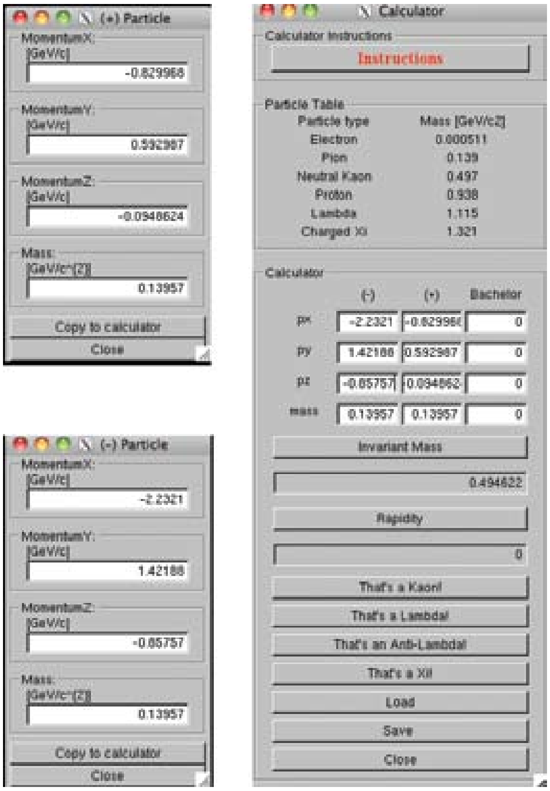


Figure 7. *Track information (left) and invariant mass calculator (right).*

The event display shows three views of the ALICE detector (3-dimensional view, rφ projection and rz projection). The pupils can scan events, displaying the clusters and tracks and highlighting the V0s (and cascades). Once a V0 is found, the rest of tracks and clusters of the event can be removed from the display so that only the tracks associated with the V0 are shown. The colour convention is that positive tracks from V0s are red, negative tracks are green (and "bachelors", in the case of cascades, purple). All this is shown in Fig. 6. By clicking on each track the values of the momentum components and the particle mass, (the one with the maximum probability, from the particle identification algorithms) appear on a little box (fig. 7 left). This information can be copied to the calculator, which then calculates the invariant mass of the mother particle (fig. 7 right).

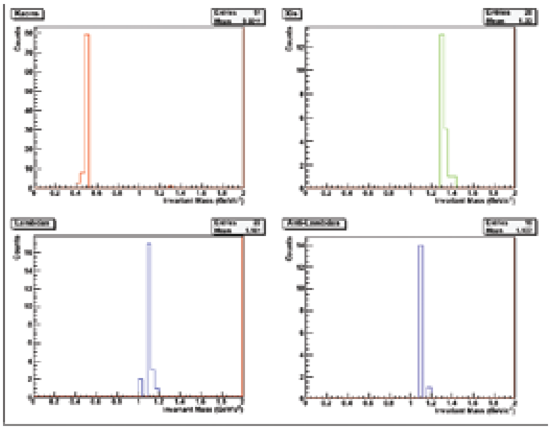


Figure 8. *Invariant mass histograms for K^os Λ, anti-Λ and Ξ^-.*

At its present state the program includes four invariant mass histograms (for K^os Λ, anti-Λ and Ξ^-). After inspecting each V0 decay the pupils will identify it from the decay products and the invariant mass value (a reference table with the masses of some particles is given as part of the calculator, see Fig. 7). The invariant mass histograms can be displayed, as shown in Fig. 8.

In addition rapidity calculation and histograms have been implemented; these have been foreseen for university students.

5. The exercise

The analysis part consists of the identification and counting of strange particles in a given event sample, typically containing 100 events.

Strange Particle Statistics

Strange Particle Statistics

Particle	MC Data	Real Data
Kaons	13.4	22
Lambdas	3.9	3
antiLambdas	3.5	5
Xis	5.5	5
DO THEY AGREE?	YES!	NO!

Close

Figure 9. *Table with number of K^os, Λ, anti-Λ and Ξ^- foreseen by theory (MC Data, left column) and measured in a 100-event sample (real data, right column).*

Their numbers can then be compared with the values predicted by theoretical models and used in Monte Carlo generators, such as Pythia. To facilitate this comparison, a table is filled, as shown in Fig. 8. The column on the left contains the number of K^o s, Λ, anti - Λ and Ξ^- corresponding to 100 events (in this case 900 GeV proton-proton interactions) as in the Monte Carlo; the column on the left contains the numbers measured in a 100-event sample.

Strange Particle Statistics

Particle Ratios

Particle Ratio	MC Data	Real Data
Kaons/Pions(+)	0.094	0.123
Lambdas/Pions(+)	0.026	0.031
antiLambdas/Pions(+)	0.024	0.020
Xis/Pions(+)	0.037	0.0270
DO THEY AGREE?	YES!	NO!

Close

Figure 10. *Table with ratios of strange to non-strange particles (pions) foreseen by theory (Monte Carlo) on the left; measured in a 100-event sample on the right.*

The number of each strange particle species (found in a 100-event sample) is divided by the average number of pions corresponding to 100 events. These ratios of strange to non-strange particles are compared with the theoretical ones, where no strangeness enhancement is foreseen. It can thus be decided if strangeness enhancement is observed. These ratios are shown in Fig. 10.

6. Status and future

Event samples have been produced, containing events with K^os, Λ, anti-Λ and Ξ^- as well as events without strange particles. The data used were recorded during the first weeks of LHC operation, during November and December 2009; they correspond to 900 GeV proton proton collisions. The numbers of strange particles per sample of 100 events have been enhanced with respect to the "real" numbers measured from the data analysis: an enhancement factor of 100 has been used for K^os, Λ and anti-Λ and a factor of 1000 for the case of the rarer Ξ^-.

Event samples from 7 TeV proton proton collisions will be created in the future. When LHC provides lead lead collisions, samples with events from these heavy ion collisions will be created. At that point the exercise can really “look for quark gluon plasma” based on the strangeness enhancement signature.

7. References

[1] http://www.physicsmasterclasses.org/exercises/manchester/en/

[2] The ALICE experiment at the CERN LHC, K. Aamodt et al. (the ALICE Collaboration), JINST, 3, S08002 (2008) http:// iopscience.iop.org/1748-0221/3/08/S08002

[3] EVE - Event Visualization Environment of the ROOT framework, M. Tadel, PoS AC AT (2008)103; http://pos.sissa.it//archive/conferences/070/103/ACAT08_103.pdf

[4] ROOT — A C++ framework for petabyte data storage, statistical analysis and visualization , F. Rademakers, P. Russo and M . Tadel, Computer Physics Communications; Anniversary Issue; Volume 180, Issue 12, December 2009, Pages 2499-2512. http://dx.doi.org/10.1016/j.cpc.2009.08.005

Particle Collisions for Students and Teachers

K. Erik Johansson
Department of Physics, Stockholm University,
AlbaNova, 106 91 Stockholm, Sweden
E-mail: kej@physto.se

Abstract

Particle collisions, using the world's largest physics experiments, makes it possible for students and teachers to get close to the forefront of scientific research. The ground breaking results that are possible from these giant, international collaborations of physicists, can amaze, inspire and interest both students and teachers. Education projects like Hands on CERN has become the model for how to use real particle collisions at the Large Electron Positron collider at the CERN particle physics laboratory for education purpose. With the recent start of the Large Hadron Collider at CERN, particle collisions at the largest energy ever created in a laboratory will primarily be used in basic research to explore the mysteries of energy and matter, but will also be used in innovative education projects making it possible for students and teachers to explore the particle collisions registered in the ATLAS experiment.

Keywords

Particle physics, particle collisions, Masterclasses, Hands on CERN, ATLAS experiment. Large Hadron Collider, CERN.

1. Introduction

One of the aims with the education projects using real particle collisions from the leading world particle physics experiment, is to enthuse students and teachers at school for modern physics in general and particle physics in particular, and to give them a chance to understand and appreciate how today's physics research is being done. With Hands on CERN the additional physics aim was to introduce in an interesting and dynamic way the fundamental building blocks of nature, the quarks and leptons. The electron is the lepton that we find all around us, but there are also others playing a role in the world of particles.

At the recently started Large Hadron Collider at CERN, the ATLAS experiment is well placed to make ground breaking discoveries that will change the way we perceive the world. The collision energies are the highest ever achieved in a laboratory. To explore the intricacies of the particle collisions, the students and teacher will need special analysis tools, very similar to the tools and methods the scientist use. The education projects of the ATLAS experiment provide the students with particle physics data and descriptions of particle physics, the experiment and the analysis tools.

2. The Hands on CERN Education Project

Data from the DELPHI experiment at the CERN Large Electron Positron Collider have been used for about 15 years in the innovative education project Hands on CERN [1,2], and it is still being used. Using digitised scientific data transmitted from the DELPHI experiment via Internet, schools can approach the physics frontline in the classroom. Students and teachers have been able to take part in a modern scientific experiment and explore the same scientific information as the scientists.

The primary aim was to:

- explore the building blocks of nature - the quarks and leptons
- explore the fundamental forces in nature
- make modern science experiments available in schools

2.1 DELPHI particle collisions

The particle collisions are used to study the quarks and the leptons, the fundamental building blocks in nature. The experimental data are from the DELPHI experiment [3] at the Large Electron Positron Collider (LEP) at CERN, the European particle physics laboratory [4]. At LEP electrons and positrons, the antiparticle of the electron collided at high energy. During the first phase of LEP the collision energy was 91 GeV, enough to produce the Z^0 particle, the mediator of the electroweak interaction. LEP was closed in 2000, and the accelerator ring now contains the Large Hadron Collider (LHC). The DELPHI experiment has become a monument from the LEP époque and can sometimes still be visited down in the cavern close to the Large Hadron Collider.

The following particles and processes can be explored with Hands on CERN:

- quarks and leptons
- the decay of the Z^0 and W particles
- the electroweak and strong interaction
- the gluon, the mediator of the strong interaction

2.2 The Education Material

The main parts of the education material are the 3D event display of particle collisions and the more game-like playing with quarks and particles part. In addition the website contains background information about the Standard Model of microcosm and the basics of accelerator and particle detectors.

The main dynamic part of Hands on CERN is the WIRED event display [5] and the 1500 particle collisions from the DELPHI experiment. The 3D event display is controlled with rotate and zoom buttons, and the different particle detectors of the DELPHI experiment can be introduced on the display in order to identify some of the produced particles and identify the particle interaction.

2.3 The particle events

At a collision energy of 91 GeV a Z^0 particle is produced in the electron positron collision. It rapidly transforms into a quark and an anti-quark or a lepton and an anti-lepton, where the lepton is either an electron, a muon or a tauon (Figs. 1, 2).

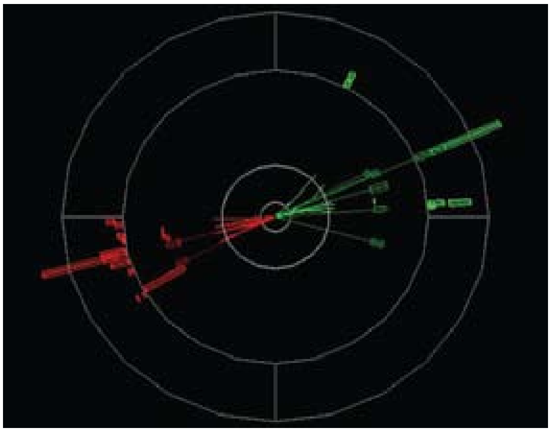


Figure 1 *Two-jet event. The production of a Z^0 particle decaying into a pair of quarks (a quark and an antiquark) giving rise to two jets of particles deposing their energy in the calorimeters (rectangles).*

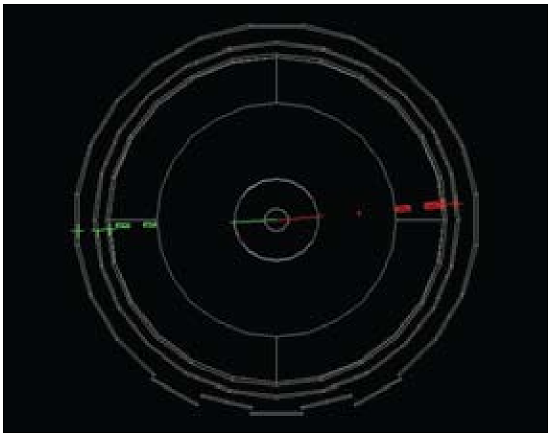


Figure 2 *The production of a Z^0 particle decaying into a pair of muons traversing all the detectors out to the muon detectors.*

The quark gives rise to a jet of particles (Fig. 1), and the most common configuration is the production of a quark and an antiquark, which are observed as two jets of particles. One of the quarks can radiate a gluon, the mediator of the strong interaction, and give rise to a third jet of particles. The probability for this to happen is proportional to the strong coupling constant, α_s and the two-jet and three-jet events are used to determine the value of the α_s.

At a collision energy exceeding 160 GeV two W particles can be produced. Each of these can decay into two quarks or into a charged lepton like electron, muon or tauon plus a corresponding neutrino. The two W particle decays can give rise to rather complex events, which are more difficult to entangle.

2.4 International recognition

Hands on CERN has been translated to 15 languages including the two original languages (Swedish and English). These translations were done either for the International Masterclasses or spontaneously by teachers or scientists who wanted to use the education project in their classes or courses. During the last few years Hands on CERN has received a lot of international attention culminating in the prestigious Webby Award in the Science category [6].

3 International Masterclasses

The International Particle Physics Masterclass [7] provide opportunities for students and teachers to take part in an authentic research process in a University or research laboratory. This is an interesting way to improve the understanding of scientific research and to give high school students and teachers a possibility to interact with physicists in the field and learn how today's physics research is being done on an international level. Particle Physics Masterclasses provide this opportunity once per year by inviting high school students to spend one day at one of the participating universities or research centres, where they attend lectures and perform measurements on real data from particle physics experiments (Fig. 3). By using the same tools as professional scientists, the measure¬ments mirror the research process and the activities of researchers in particle physics.

Figure 3a *Masterclass Students at House of Science in Stockholm, Sweden working with Hands on CERN events.*

Figure 3b *Students at Athens Technical University in Greece taking part in a Masterclass event.*

The primary aims of Particle Physics Masterclasses are to:

- stimulate the interest in today's physics explorations
- demonstrate the scientific research process
- explore the fundamental forces and building blocks of nature

To achieve these aims, real data of particle physics experiments are visualised using original "event displays" of the particle collision and the produced particles. Introductory lectures teach the students the basics of particle physics, particularly how to interpret the particle collisions and to identify different sorts of elementary particles. With this information the students are able to perform their own measurements and determining many of the properties of the Z particle. The data were from the DELPHI and OPAL experiments at CERN's Large Electron Positron Collider LEP, operational from 1989 to 2000. The Hands on CERN educational material was extensively used during all the International Masterclasses.

At the end of each day all student groups at the four to six participating sites (Fig. 4) take part in a joint video session from CERN. During the video session the students act as members of an international collaboration, performing tasks similar to those of the scientists. Informal meetings with the local particle physics researchers give the masterclass participants the feel of taking part in a real research activity.

Figure 4 *A Masterclass video session in Dresden, Germany.*

Each year about 5000-6000 high school students in more than twenty countries come to one of close to a hundred universities or research centres for one day in order to explore the intricacies of particle physics. Since the beginning in 2005 around 30 000 students have taken part in an International Masterclass event.

3.1 The response of the students

Amazingly the students learned very quickly how to use the event display, and had no problems to identify the different particle decays of the Z particle. Some of the students wanted more challenging tasks and attacked a small sample of the rather complex events with two W particles produced.

The evaluation of the Masterclasses based on the response of close to 1300 students aged between 16 and 19 years revealed the interest of the students and the success of the Masterclasses [8]. One of the interesting results was that the perception of men (around 70% of the participants) and women (around 30% of the participants) of the Masterclasses were very similar and they found the Masterclasses equally interesting.

3.2 Evaluation results

An overwhelming majority of the students liked the Masterclass much or very much (82%), while only 4% of the participants did not enjoy the program. There were no significant differences between the males and the females. It was interesting to note that the appreciation of the Masterclasses was independent of the students' pre-knowledge of particle physics. Both those who knew little and those who knew quite a lot about particle physics appreciated the program to very much the same extent.

The perception of the lectures was an important factor for the appreciation of the Masterclasses. The students' perception of the program were rated on a 5-point Likert scale with "1" showing no agreement at all and "5" reflecting full agreement with the statement. Fig. 5a (from Ref. 8) shows that a large majority of the participants found the lectures interesting (81%), and Fig 5b shows a clear correlation between interesting lectures and the overall appreciation of the Masterclasses, with small differences between the males and the females.

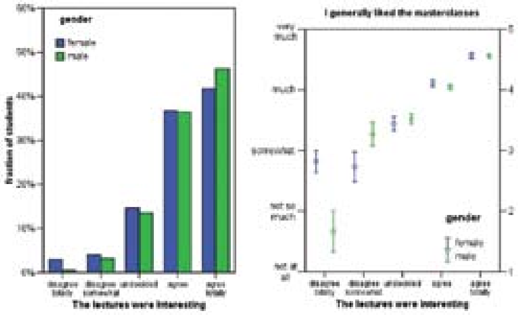


Figure 5 *The popularity of the lectures (a) and the popularity of the Masterclasses as a function of the Masterclass popularity (b).*

The masterclass exercises included quite a lot of computer work with particle collision data, but it was interesting to note that there was no correlation between the amount of computer work at home and the appreciation of the Masterclasses. Those using computers very little appreciated the Masterclasses like those using computers a lot. More details about the evaluation of the Masterclasses are found in Ref. 8.

4. The Education project of the ATLAS Experiment

LEP, the electron-positron collider closed down in 2000, but the study of high-energy particle collisions is continuing. In the tunnel that housed the LEP collider a new collider for accelerated protons has been installed – the LHC (the Large Hadron Collider).

4.1 The ATLAS experiment

ATLAS [9] is one of the major particle physics experiments at the Large Hadron Collider at CERN. The aim is to explore the fundamental nature of matter and the basic forces that shape our universe and to reveal the secrets of nature in the head-on collisions of protons of extraordinarily high energy. ATLAS is one of the largest collaborative efforts ever attempted in the physical sciences. There are 3000 physicists including 1000 students participating from 174 universities and laboratories in 38 countries. The detector, located 100 metres underground, has a length of 46 metres and a height of 24 metres (Fig. 6).

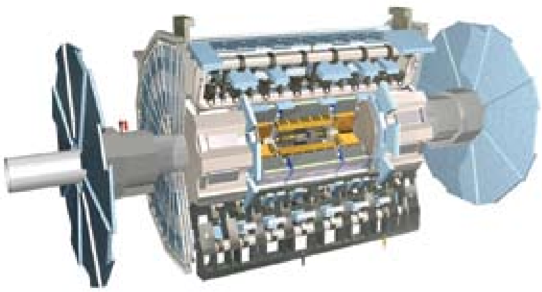


Figure 6 *The ATLAS detector with some persons to indicate the scale.*

The protons are accelerated in the Large Hadron Collider, an underground accelerator ring 27 kilometres in circumference at the CERN Laboratory in Geneva, Switzerland [4]. The particle beams are steered to collide in the middle of the ATLAS detector. The energy density in these high energy collisions is similar to the particle collision energy in the early universe less than a billionth of a second after the Big Bang. Fig. 7 shows a high-energy particle collisions recorded in the ATLAS detector.

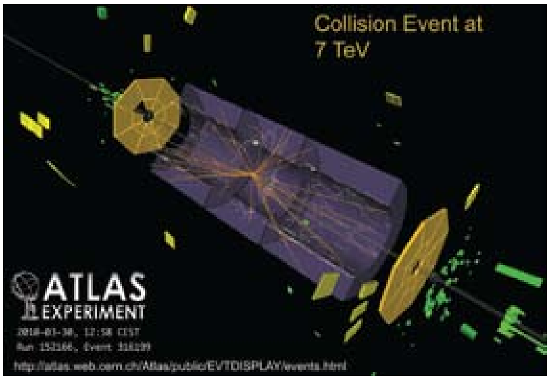


Figure 7 *A high-energy particle collision recorded in the ATLAS detector*

4.2 Event analysis

The ATLAS Event Challenge will be an innovative program providing students with access to real and simulated data to explore the world of particles. The ATLAS Event Challenge is modelled on the two very successful education projects, QuarkNet [10] and Hands on CERN [1,2], in which we have substantial experience and involvement.

The European Commission financed project "Learning with ATLAS@CERN" [11] has been very important in making the ATLAS Event Challenge possible. Since the first physics run at 900 GeV collision energy in December 2009, ATLAS can now offer real particle collisions to students and teachers. These events contain the strange particles K^0 short with a lifetime of 0.9 10^{-10} s and the Λ^0 particle with a lifetime of 2.6 10^{-10} s. These particles are called strange particles as they contain a strange quark. The advantage with these particles is that the decay point is easily visible using the ATLAS reconstructed data (Fig. 8). The mass of the K^0 and Λ^0 particles can be determined knowing the mass and momenta of the particles produced in the decay.

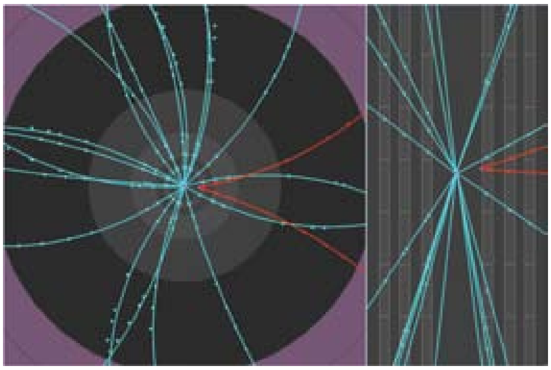


Figure 8 *A neutral Ko particle observed to decay into two charged particles (in red) in two views of the event.*

4.3 Special Relativity

It is a challenge to repeat the success of the Hands on CERN education project using the collisions in the ATLAS experiment. Sophisticated analysis tools will be needed in order to extract the interesting information from a wealth of particle collisions and a wealth of data for each event. In addition a minimum of special relativity is needed to detect and reconstruct the "invisible" particles, which very often are the focus of the physicists. The mass, the "invariant mass" of the invisible particle can be determined when the trajectories and momenta of the particles it decays to have been measured in the detector. The invariant mass is independent of the movement of the decaying particle. Fig. 8 shows the decay of a neutral K0 particle produced in a proton-proton collision in the middle of the ATLAS detector. Its mass and lifetime can be determined by measuring the tracks (red in the figure) that the particle decays into.

5. Summary

The particle physics projects using real particle collision data from one of the world's leading particle physics laboratories confronts the students with contemporary physics at its most fundamental level. Today's technology plays an important role in fundamental research, where the huge particle accelerators and detectors produce and detect high energy particle collisions which are used to explore the interior of matter and to produce particles that were abundant at the beginning of the Universe.

The Hands on CERN education project on the web has been the model for the use of real particle collision data in schools. It has contributed to the success of the International Masterclasses, which has reached close to 30 000 students during 2005-2010. With the start-up of the Large Hadron Collider in 2009, a new era in particle physics exploration has started. The particle collisions from the ATLAS experiment can now be used in school and University education. At present real particle collision data contain the strange particles like K^0 and Λ^0, but in the near future students will also be able to explore particles like the Z and W particles, produced in the high-energy particle collisions in the ATLAS detector. The ATLAS Education and Outreach project has been very successful in producing education material like brochures, posters, a film and animations about ATLAS and particle physics, which are attractive to use in combination with the exploration of real particle collision data. The ATLAS Education and Outreach project has played an important role in promoting today's physics like particle physics, and encouraging school teachers to introduce modern physics.

6. References

[1] Hands on CERN website: http://hands-on-cern.physto.se

[2] K.E. Johansson, Hands on CERN – a well-used physics education project, Physics Education 41 (2006) 250-254.

[3] DELPHI website: http://www.cern.ch/Delphi/Welcome.html

[4] CERN website: http://www.cern.ch

[5] Coperchio M C, Dönszelmann M, De Groot N, Gunnarsson P, Limaath M, McNally D and Smirnov N, 1998 Comp. Phys. Commun. 110, 155

[6] Webby Award website: http://www.webbyawards.com/ In 2005 the author received a Webby for the Hands on CERN science education project.

[7] International Masterclasses http://www.physicsmasterclasses.org/

[8] K.E. Johansson, M. Kobel, D. Hillebrandt, K. Engeln, and M. Euler, European Particle Physics Masterclasses make Students Scientists for a Day, Physics Education 42(2007) 636-644.

[9] ATLAS experiment public website: atlas.ch

[10] QuarkNet webpage: http://QuarkNet.fnal.gov and documentation references

[11] The Learning with ATLAS web portal: http://www.learningwithatlas-portal.eu

Science in the schools - the Extreme Energy Events project

M. Abbrescia[1], R. Antolini[11], R. Baldini Ferroli[6][7], G. Bencivenni[7], E. Bressan[2], A. Chiavassa[8], C. Cicalò[10], L. Cifarelli[2], F. Coccetti[11][6], D. De Gruttola[12], S. De Pasquale[12], M. D'Incecco[11], F. L. Fabbri[7], V. Frolov[8], M. Garbini[2], C. Gustavino[11], D. Hatzifotiadou[2][*], P. La Rocca[4][6], F. Librizzi[4], A. Maggiora[8], H. Menghetti[2], S. Miozzi[7], R. Moro[11][6], M. Panareo[9], G. Piragino[8], F. Riggi[4], F. Romano[1], G. Sartorelli[2], E. Scapparone[2], M. Selvi[2], S. Serci[10], E. Siddi[10], M.C.S. Williams[2], A. Zichichi[2][6][5] and R. Zuyeuski[3]

(1) INFN and Dipartimento di Fisica, Università di Bari - Bari, Italy
(2) INFN and Dipartimento di Fisica, Università di Bologna - Bologna, Italy
(3) World Laboratory - Geneva, Switzerland
(4) INFN and Dipartimento di Fisica e Astronomia, Università di Catania - Catania, Italy
(5) CERN - Geneva, Switzerland
(6) Museo Storico della Fisica, Centro Studi e Ricerche E.Fermi (Centro Fermi)- Rome, Italy
(7) INFN, Laboratori Nazionali di Frascati - Frascati (RM), Italy
(8) INFN and Dipartimento di Fisica, Università di Torino - Torino, Italy
(9) INFN and Dipartimento di Fisica, Università di Lecce - Lecce, Italy
(10) INFN and Dipartimento di Fisica, Università di Cagliari - Cagliari, Italy
(11) INFN, Laboratori Nazionali del Gran Sasso - Assergy (AQ), Italy
(12) INFN and Dipartimento di Fisica, Università di Salerno - Salerno, Italy

(*) presented by despina.hatzifotiadou@cern.ch

Abstract

The Extreme Energy Events (EEE) project aims to study extended air showers from high energy cosmic rays and extreme energy events by detecting the muon component of the shower. To achieve this goal, a network of muon telescopes has been installed in high schools distributed all over Italy. Each muon telescope consists of three large area (80 x 160 cm2) Multigap Resistive Plate Chambers (MRPCs). Each MRPC has 24 pickup strips read out at both ends; the hit position along the strip is thus deduced from the time difference. This design offers pointing capability, so that the muon direction can be reconstructed. The project has been conceived by Prof. A. Zichichi in order to rekindle the interest of young people in science and give them a first-hand experience of scientific research.

Keywords

cosmic rays, extreme energy events, multigap resistive plate chambers, muon telescope.

1. Introduction

The Extreme Energy Events (EEE) project aims to study extended air showers from high energy cosmic rays and extreme energy events by detecting the muon component of the shower. To achieve this goal, a network of muon telescopes has been installed in high schools distributed all over Italy. The project has been conceived by Professor A. Zichichi in order to rekindle the interest of young people in science and give them a first-hand experience of scientific research. To ensure their full involvement in all stages of the project, they participate in the construction of the muon detectors, setting up and commissioning of the telescopes, installation in the schools and the data-taking and analysis. The project is financed by the Italian Ministry for Education, Universities and Research (MUIR), the National Institute for Nuclear Physics (INFN) and the "Centro Studi e Ricerche e Museo Storico della Fisica Enrico Fermi"; CERN is also a partner in the project.

2. The detector

The requirements that led to the design of the muon telescopes and the choice of the detectors for the EEE project were: large area coverage, ease of construction and pointing capability, so that the direction of incoming muons can be reconstructed. Each muon telescope consists of three large area (80x160 cm2) Multigap Resistive Plate Chambers (MRPCs). These are gaseous detectors of the parallel plate type and consist of a stack of resistive plates made of commercial glass. The distance between the glass plates is kept fixed by means of nylon fishing line spacers in a zig-zag layout. This MRPC has 6 gas gaps with a gap width of 300 microns. The external glass plates, 1.9 mm thick, have their outside surface painted with a conductive layer; this is to apply the high voltage needed for the chamber operation; the intermediate plates, with a thickness of 1.1 mm, are electrically floating. A cross section of this MRPC is shown in Fig. 1. This design is based on the 10 gap MRPCs used for the Time of Flight (TOF) system of the ALICE experiment at LHC [1].

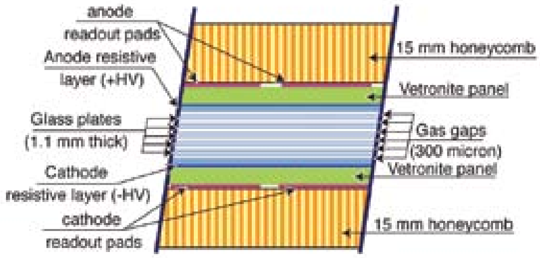


Figure 1. *Cross section of the MRPC for the EEE project.*

Charged particles going through the MRPC ionise the gas; the electrons produced from the ionisation are multiplied due to the high electric field and avalanches are created inside the gas volume; their movement towards the anode induces electrical signals on pick-up strips. The intermediate glass plates physically stop the development of the avalanches, but they are transparent to the induced signal; thus the signal picked up at the readout electrodes is the sum of the signals from all avalanches created in all gas gaps. The advantage of this multigap design is that the time precision of the signal is correlated with the gap width; this results in an excellent time resolution.

The readout is done with 24 pickup strips, made of adhesive copper tape glued on a vetronite plate, as shown in Fig 2. The width of the strips is 2.5 cm and the distance between them is 7 mm. There are pickup strips both at the anode and the cathode, and in this way a differential signal is sent to the readout electronics.

The MRPC is placed in an aluminium, gas tight box, with dimensions 200 x 100 x 5 cm2.

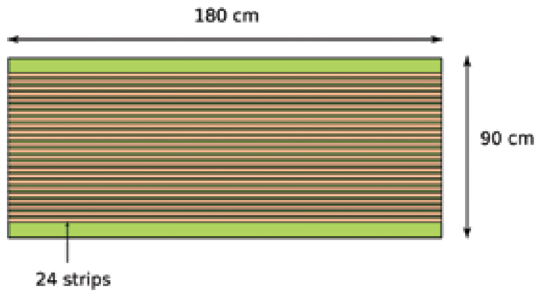


Figure 2. *Readout strips made of copper tape glued on vetronite.*

3. Electronics and readout

The front end electronics is based on the ultrafast NINO amplifier and discriminator developed for the ALICE TOF [2,3]. This is a low-power, 8-channel chip, which accepts differential input and produces LVDS output. The leading edge of the signal provides the time measurement; the trailing edge is used to calculate the time width. The width of the LVDS signal is dependent on the input charge, thus the width is used for slewing corrections. The front end cards have 3 NINO chips, with a total of 24 channels, which matches the 24 strips per readout plane. Each 24-channel card also provides an OR of the 24 inputs. Two such cards are used for each MRPC to read out the signals from both ends of the pickup strips. The hit position along the strip is obtained from the time difference.

The trigger is created by a six-fold coincidence of the OR signals from both sides of all three MRPCs. A home-made (Catania - CERN) trigger card is used in most of the EEE stations, a variant of the ALICE LTU is used in others; the trigger can alternatively be formed by standard NIM electronics.

A VME based system is used for the readout. Commercial TDCs are used to measure the time of the hits from the MRPCs: CAEN V1190A with 128 channels and CAEN V1190B with 64 channels. These are based on the High Performance Time to Digital Converter (HPTDC) [4], developed by the CERN microelectronics group, in the 100 ps/bin mode. A GPS card (HYTEC) is included in the readout, providing the absolute time stamp needed to correlate events from different stations.

The Data Acquisition is done by running a LabView programme on a Windows PC. The communication between the PC and the VME crate is done by the CAEN V1718 USB bridge. In addition to data readout and recording, the programme used for data acquisition provides online monitoring of the raw data.

4. The MRPC construction

The construction of the MRPCs for the muon telescopes took place at CERN, in the laboratory and assembly hall of the ALICE TOF. Italian High Schools participating in the project have been sending groups of 5-10 persons, consisting of pupils and teachers, accompanied by researchers from the University or INFN section from the same town or a neighbouring one. Each group stayed a period of a week and constructed, under the supervision and guidance of INFN/ CERN physicists, the chambers for their muon telescope.
There were construction periods of 2-3 months in 2005, 2006 and 2009.

A total of more than 100 MRPCs have been built from the beginning of the project until now.

Figure 3. *Making a readout plane: Glueing copper strips on a vetronite sheet.*

Details on the chamber construction procedure, including preparation of the different components, are given in ref. [5]. Fig.3,4,5 show photographs of some of the construction steps (preparation of the readout plane; stretching the fishing-line spacers; lifting of the glass plate).

Figure 4. *Stretching the fishing line spacer in a zig-zag pattern between glass plates.*

Figure 5. *Lifting a glass plate with a vacuum system to position it on top of the previous one.*

This was a valuable experience for the pupils, from various aspects. Using their own hands to construct a detector that works was very important, especially as many of them were using tools (to drill holes, to solder etc) for the first time. After the end of the construction the pupils had the opportunity to get some experience with operating gaseous detectors. They flowed gas through the chambers, checked the gas-tightness, hunted for and repaired leaks. They slowly increased the high voltage and monitored the dark current. Eventually they measured the efficiency plateau.

5. Chamber performance

The performance of the MRPCs for the EEE muon telescopes has been studied extensively, both with cosmic rays [6] and in a test beam at the CERN East Hall [5]. The MRPCs are filled with a gas mixture of 98% Freon C2F4H2 and 2% SF6 and are operated in avalanche mode. For a voltage difference between anode and cathode in the 18 kV range their efficiency is better than 95% and the time resolution (σ) is of the order of 100 ps. This results in a position resolution of the order of 1 cm along the readout strip; thus the muon direction is reconstructed with an angular resolution of 0.3° (RMS).

6. Installation of the muon telescopes

After their construction and first tests at CERN, the muon chambers were transported to Italy and distributed to the schools participating in the project. Fig. 6 shows one of the methods used for packaging in order to ensure that the glass plates do not break during transport.

Figure 6. *The 3 MRPCs of a muon telescope, inside their aluminium boxes, packaged with boat fenders for safe transport.*

Figure 7. *A muon telescope on its support frame in the Gran Sasso laboratory.*

Each school was equipped with a mechanical support structure, offering the possibility to vary the distance between the MRPC planes (typical distances are between 50 cm and 100 cm); a telescope on its support is shown in Fig. 7. The schools were also equipped with a gas mixing system (Bronkhorst), a special cupboard to contain the gas bottles, and the front end, trigger and readout electronics, described in section 3.

The High Voltage necessary for the MRPC operation is provided by DC-DC converters, as the use of High Voltage cables is not allowed in the schools for security reasons. Two such converters per chamber are used, providing positive and negative output of 0-10 kV for an input of 0-5 V.

7. Status of the project

At the moment there are 33 muon telescopes installed in Italian high schools and two at CERN; their geographical distribution is shown in Fig. 8. Many of them are taking data; others are in various stages of being equipped with front end and readout electronics, commissioned and debugged. There is also a long list of schools interested in joining the project.

The stations that take data analyse them locally and, in addition, transfer them to the Ettore Majorana Centre for Scientific Culture (EMCSC) where they are stored.

Figure 8. *Map of Italy showing the towns where EEE telescopes have been installed; the numbers inside the stars correspond to the number of telescopes.*

8. First coincidence results

Extensive air showers have been detected with the EEE project telescopes [7]. Using two telescopes installed in two High Schools in L'Aquila, at a distance of 180 m from each other, the first time coincidences have been observed. The track reconstruction achieved with the MRPCs allows to reduce the background due to accidental coincidences and determine the shower axis.

9. References

[1] A.V. Akindinov et al., Nucl. Instr. Meth. Phys. Res. A 56 (2000) 16-122.

[2] F. Anghinolfi, P. Jarron, A.N. Martemiyanov, E. Usenko, H. Wenninger, M.C.S. Williams and A. Zichichi, Nucl. Instr. Meth. Phys. Res. A 533(2004) 183-187.

[3] F. Anghinolfi, P. Jarron, F. Krummenacher, E. Usenko and M.C.S. Williams, IEEE Transactions on Nuclear Science, Vol. 51, No 5, Oct. 2004, 1974-1978.

[4] J. Christiansen, http://tdc.web.cern.ch/tdc/hptdc/docs/hptdc_manual_ver2.2.pdf

[5] M. Abbrescia et al., Nucl. Instr. Meth. Phys.Res. A 593 (2008) 263-268.

[6] Shaohui An, D. Hatzifotiadou, Jinsook Kim, M.C.S. Williams, A. Zichichi and R. Zuyeuski, Nucl. Instr. Meth. Phys. Res. A 578 (2007) 139-145.

[7] M. Abbrescia et al., Il Nuovo Cimento, Vol. 125B, N.2, 243-254.

The Education and Outreach Centre of the ATLAS Experiment

R. Michael Barnett[1] and K. Erik Johansson[2]
[1]*Lawrence Berkeley National Laboratory, Berkeley, USA*
E-mail: barnett@lbl.gov

[2]*Stockholm University, AlbaNova, 106 91 Stockholm, Sweden*
E-mail: kej@physto.se

Abstract

With the extraordinary possibility to make groundbreaking discoveries, the ATLAS Experiment at the Large Hadron Collider in Geneva has an opportunity to explain particle physics to a wider audience and play an important role in promoting contemporary physics at school. For more than 13 years ATLAS has had a substantial collaborative Education and Outreach project in which ATLAS physicists from various parts of the world take part. ATLAS is presently taking data at the Large Hadron Collider at CERN at the highest energy ever achieved in a laboratory. These particle collisions can be used by students to explore the fundamental processes of physics.

Keywords

Particle physics, particle collisions, ATLAS experiment, Large Hadron Collider, CERN, films, animations, student projects.

1. Introduction

The ATLAS Experiment has the ambition to participate in educating the next generation of scientific leaders and to share with students and the general public the knowledge one gains about the fundamental processes from the exploration of high energy particle collisions [1]. It will also play a role in developing science literacy and communicating why and how science is done. ATLAS is present on many different arenas, such as the web (including blogs, YouTube, etc.) and even a Hollywood film. This gives several possibilities to discuss the scientific results, the basic nature of matter, energy, space, and time.

Today's modern society is to a large extent based on technological innovations and inventions derived from discoveries in natural science. In order to capture students' interest in physics, the large experiments at the physics frontier could play a more important role in shaping today's physics education and complement the traditional teaching of physics. Scientific education and outreach, and the promotion of awareness and appreciation of physics research, has become an important task for the research community.

ATLAS decodes the "events" that unfold after the head-on collisions of protons (Fig. 1); these collisions occur in the Large Hadron Collider (LHC) with unprecedented energies. Students and others will be excited as they can explore some of the same events as the physicists, and use some of the same analysis tools to find known and unknown particles, and possibly signs for Higgs bosons, dark matter, and extra dimensions of space.

An extraordinary opportunity and capability to impact education and outreach worldwide is available to the ATLAS Experiment at LHC. This single experiment consists of 3000 physicists (including 1000 graduate students) from 38 countries on every continent.

Fig. 1 *A collision event in the ATLAS detector. The total collision energy is 7 TeV ; each of the colliding protons have an energy of 3.5 TeV.*

The ATLAS Experiment is developing a program that will use the best aspects of technical animation by allowing students and others to manipulate 3D images of the detector, component by component, and then look to see how particles are detected as they pass through the different layers of particle detectors. In addition, students will look at animations of events representing new physics such as dark matter or extra dimensions, and will eventually be able to control and analyse 3D images of these events.

2. The ATLAS experiment

The ATLAS particle physics experiment [2] is exploring the fundamentals of matter and the basic forces that shape our universe. The aim is to reveal the secrets of nature in the head-on collisions of protons. ATLAS is one of the largest collaborative efforts ever attempted in the physical sciences.

The protons are being accelerated in the Large Hadron Collider, an underground accelerator ring 27 kilometres in circumference at the CERN Laboratory in Geneva, Switzerland [3].

The particle beams are steered to collide in the middle of the ATLAS detector, located 100 metres underground, with a length of 46 metres and a height of 24 metres (see Fig. 2). The debris of these collisions reveals fundamental particle processes. The energy density in these high-energy collisions is similar to the particle collision energy in the early universe less than a billionth of a second after the Big Bang.

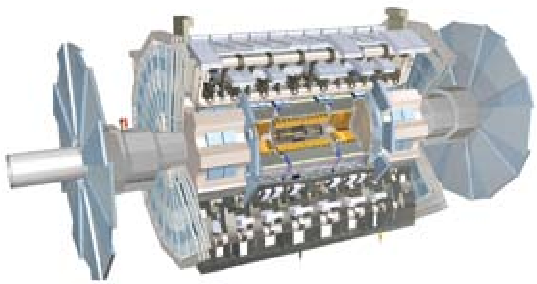


Fig. 2 *The ATLAS detector with people to indicate the scale.*

3. The ATLAS Education and Outreach Centre

The ATLAS Education and Outreach Centre has existed since 1997. Its regular meetings attract a large number of interested people from the 174 ATLAS institutions. They take active part in the discussions and give strong support to the activities and projects.

The aims of the ATLAS Education and Outreach group are to:

- Inform, intrigue, and inspire the public, students, and teachers about the ATLAS Experiment and particle physics
- Provide teachers and the members of the ATLAS collaboration with information and material to assist in their contacts with the public, officials, news media and students
- Facilitate the teaching of particle physics at school and universities by providing ideas and interesting educational material
- Coordinate ATLAS outreach activities.

4. Informational material

The ATLAS informational material exists in different forms:

- An extensive website (including news, blog, twitter, YouTube, etc.)
- Many printed materials and posters
- Videos
- Animations
- CD's and DVD's
- A massive mural at the ATLAS site
- Imaginative items such as a pop-up book and 3D viewer

Most of the ATLAS information material can be downloaded from the public website http://atlas.ch [2], which describes the basic ingredients in a particle physics experiment and has electronic tours of the theory of particle physics, the accelerator and the detector. The brochures and posters are descriptions of the ATLAS project focusing on the most interesting aspects of ATLAS.

Many of the brochures, videos, and posters have been translated to different languages by members of the ATLAS collaboration. One film for example exists in 10 languages. It has received international recognition by winning four gold medals in science video competitions [4]. The CD's and DVD's contain a rather complete set of the ATLAS information (brochures, posters, video in several languages and animations). A film based on photographs and video clips shows how the ATLAS experiment was assembled in the underground cavern. This film exists in different versions, one, three or five minutes long.

The ATLAS experiment is presently recording information of particle collisons at an energy of 7 TeV (the colliding protons have an energy of 3.5 TeV each). The latest events can be seen on the website, and some of the animations describe these real particle collisions.

The material is available through the ATLAS website, by visiting the ATLAS secretariat at CERN or from physicists at the 174 institutions that constitute ATLAS.

For films the ATLAS public website [2] and the ATLAS YouTube website [5] are the most frequented sites. In 2009 the ATLAS public website had more than 2 million hits and Youtube has had a total of close to 0.6 million viewings (Fig. 3)

Fig. 3 The ATLAS website on YouTube [5].

5. Education and outreach activities at CERN

CERN Open Day

During the CERN Open Day 16 October 2008 (Fig. 4) close to six thousand visitors descended 100 m deep underground to the ATLAS cavern to see the ATLAS Experiment at close range.

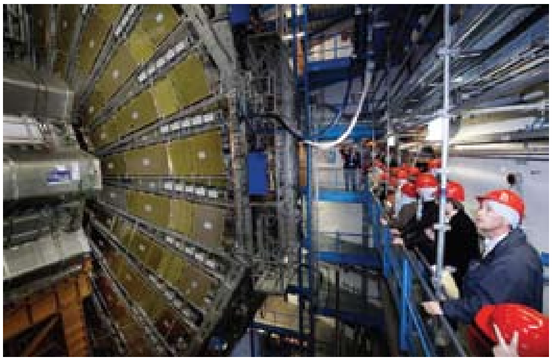


Fig. 4 *Visitors in the ATLAS underground cavern at the CERN Open Day in 2008.*

The LHC first physics event

On the 30 March 2010, CERN celebrated the LHC first physics Events (Fig. 5). More than 100 journalists visited CERN and the LHC experiments. ATLAS was visited by 10 TV crews and 27 journalists and photographers. Most of them visited the ATLAS Visitor Centre, from where the action in the ATLAS control room could be seen. CERN and ATLAS had public webcasts during the day. The ATLAS webcast had close to 300 000 viewers.

Fig 5. *The enthusiasm of ATLAS physicists when the first high-energy collisions were recorded on 30 March 2010.*

The ATLAS Visitor Centre

Year-round both ATLAS members and the CERN tour service take visitors to see the ATLAS Visitor Centre and the ATLAS control room (Fig. 6). Many of these visitors are teachers and students coming with their classes.

Fig. 6 *The ATLAS Visitor Centre overlooking the ATLAS control room.*

6. Event analysis

The ATLAS Event Challenge is an innovative program using cutting-edge technology to enhance student education, inform the public, and bring exciting exhibits/programs to science centres. It will provide these audiences with access to real and simulated data and the opportunity to participate vicariously in discoveries that may transform our thinking about our universe. This program can change the relationship between an experiment and the public/students. In addition to learning fundamental physics, students will be developing valuable communication skills using a variety of approaches or techniques (oral and written). We will build new communities among those who participate: teacher-to-teacher, student-to-student, and most importantly physicist-to-all. The ATLAS Event Challenge is modelled on the two very successful education projects, QuarkNet [6] and Hands on CERN [7,8], in which we have substantial experience and involvement.

For a few years simulated events with the production of W and Z events have been used in education projects, particularly in UK and Greece and also in Sweden. The European Commission financed project "Learning with ATLAS@CERN" [9] has been very important in making the ATLAS Event Challenge possible. Since the first physics run at 900 GeV collision energy in December 2009, ATLAS can now offer real particle collisions to students and teachers. These events contain the strange particles K^0 short with a lifetime of 0.9 10^{-10} s and the Λ^0 particle with a lifetime of 2.6 10^{-10} s. These particles are called strange particles as they had very unexpected, strange properties when they were discovered about sixty years ago. The advantage with these particles is that the decay point is easily visible using the ATLAS reconstructed data (Fig. 7). The mass of the K^0 and Λ^0 particles can be determined knowing the mass and momenta of the particles produced in the decay.

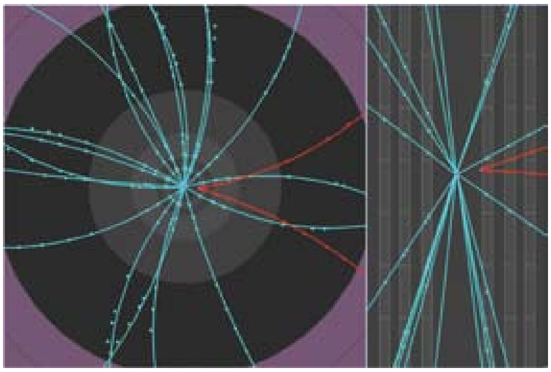


Fig. 7. *A neutral K^o particle observed to decay into two charged particles (in red) in two views of the event.*

7. Summary

The ATLAS Education and Outreach Centre has been very successful in producing informational material including printed material, posters, videos, and animations about ATLAS and particle physics. The ATLAS public website and the ATLAS YouTube site are very well utilized web sites. The ATLAS Education and Outreach Centre has played an important role in promoting activities and encouraging school teachers to introduce modern physics at school and initiating education projects with partners outside the ATLAS collaboration. It is a good model for how today's large physics experiments can promote physics at school and interact with teachers and students both at schools and universities.

8. Acknowledgements

This work has been performed within the ATLAS Collaboration, and we thank collaboration members for many useful discussions and contributions to this project.

9. References

1. R.M. Barnett and K.E. Johansson , The Education and Outreach Project of ATLAS – a new participant in physics education, Physics Education 41 (2006) 432-436
2. ATLAS website: http://atlas.ch
3. CERN website: http://cern.ch
4. Film gold medals: 1) 39th International Festival, Technology and Art TECHFILM 2001, Czech Republic, 2) World Media Festival, Hamburg, Germany, 2001, 3) The Scientific Film Box Office, Canary Islands, France 2000, 4) Prix Leonardo, 2001 International Film Festival, Parma, Italy.
5. ATLAS YouTube website: http://youtube.com/TheATLASExperiment
6. QuarkNet webpage: http://QuarkNet.fnal.gov and documentation references
7. Hands on CERN web-page: http://hands-on-cern.physto.se
8. K.E.Johansson Hands on CERN - a well used physics education project, Physics

Education 41/3(2006)251-254.

9. The Learning with ATLAS web portal: http://www.learningwithatlas-portal.eu

Mobile Applications for the ATLAS Outreach Programme

Christian Reimers
University of Vienna, Department of Astronomy
Türkenschanzstraße 17, A-1180 Vienna
reimers@astro.univie.ac.at

Alexander K Nischelwitzer
University JOANNEUM, Information Managment
Alte Poststrasse 147, A-8030 Graz
alexander@nischelwitzer.at

David Smith
Federal Ministry of Education, The Arts and Culture, IT/3 IT-Systems for Educational Purposes
Minoritenplatz 5, A-1014 Vienna
djs2206@gmail.com

Abstract

During the ATLAS Outreach Programme, several mobile applications were developed for mobile devices and their implementation into the "Learning with ATLAS@CERN" portal as online version. They are based on an interactive learning approach, which combines constructivist learning principles with the popularity of mobile devices. The innovative e-learning project called moCERN is designed to provide the learner with mobile learning using a variety of background information and brings them closer to physical phenomena.

With the help of about 20 interactive mobile learning applications that describe the most important aspects of modern physics, the user can quickly find out about all exciting areas. Due to the easy and simple operation of the various e-learning applications, it is possible to use the mobile learning programs for all users.

Keywords

Educational e-learning materials, high energy physics, mobile applications, mobile CERN (moCERN).

1. Introduction

Mobile Computing (MoCo) is one of the most challenging future fields in computer science, especially in the eLearning field. However, Mobile Computing is an umbrella term and describes any technology that enables people to access information and supports them in daily workflows independent of location.

In recent years there has been much attention focused on integrating technology with science education to improve the level of science learning and encourage more students to pursue science careers. Software development, improved pedagogical practices and an eLearning focus have contributed to an increased focus on science education. The use of mobile technology has broadened the field of eLearning extensively with its popularity and propensity to extend learning boundaries with informality and a wide range of application.

This paper describes a particular project, moCERN, and details the development of the mobile applications for high energy physics. The paper further describes the project emphasis on using the mobile technology with collaborative learning practices and concludes with the anticipated learning impact.

2. Mobile learning

Mobile applications are software applications developed specifically for mobile devices such as mobile phones. The aim was to develop an application that could be used on mobile devices as well as in the "Learning with ATLAS@CERN" portal [1] as an online version.

The applications are based on an interactive learning approach, which combines constructivist learning principles with the popularity of mobile devices. The user or learner interacts with the educational content, synthesises and processes information, then generates content, meaning and analysis from their experiences. It is a type of self-regulated learning.

The mobile applications connected with the "Learning with ATLAS@CERN" project are called mobile CERN or in short moCERN. The applications provide background information about several topics of high energy physics and used with the appropriate pedagogy brings the learner closer to physical phenomena. In Fig. 1 a screenshot of the online version of mobile CERN is presented.[2][3]

The use of mobile devices acts as a stimulus to learning, motivating learners to participate in future learning [4]. The prevalence of mobile devices amongst students at both the school and tertiary level indicates their popularity and potential. The mobile technology is presented with a portability and ease of use that makes it preferred over the range of notebooks [5]. The mobile device has a multi-faceted purpose from its use as a disruptive learning technology [6] to the ability to support individual learners. For the information gathering the mobile applications provide an introduction to the backgrounds and processes of high energy physics with little or no prior physics knowledge.

The mobile applications can be complementarily used with other scientific sources, like books, journals or web sites for more detailed physical or mathematical models. Following each application a quiz is implemented as a self assessment tool. As previously described, a website hosts also all project contributions, either for learning online or to get the applications for uploading to your mobile device.

Figure 1. *moCERN online version*

The 20 learning applications are divided into four categories of topics;

First there are general topics, such as

- CERN
- LHC
- ATLAS, etc.

Second there are specific topics,

- Higgs
- Standard model
- Accelerators, etc.

Third the topics are specialised even more,

- Cosmic Rays
- Big Bang or
- Black Holes.

And fourth there are historical or person related topics, such as

- Albert Einstein and
- Stephen Hawking.

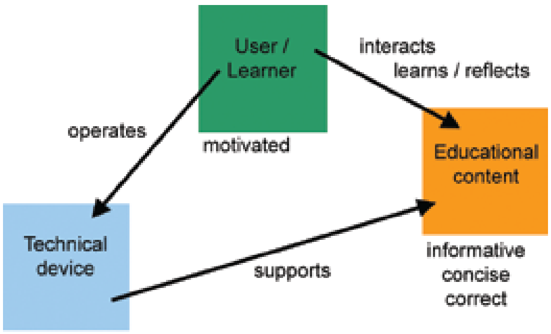


Figure 2. *Mobile learning dependencies*

3. Development process

For the development process we have to take several aspects into account (see Fig. 2). These are social, technical and educational aspects. The motivated user or learner operates the technical device, which should be user-friendly, which furthermore supports the educational content on which the user interacts, learns or reflects. The educational content should be informative, concise and also correct.

3.1. Social Aspect

The social communication aspect of mobile devices has characteristics that nave much potential for collaborative learning. The flexibility, informality and personalisation that mobile devices offer learning can extend the traditional classroom boundaries [7]. Using the social aspect characteristics, the learner's motivation is increased and users are willing to spend more time both in formal and informal settings with educational content.

Important to the social aspect of the mobile device is the design of the application. moCERN has an attractive design and layout, an "easy to use" navigational concept. The included images and animations extend and open up the presented information. In Fig. 3 you can see the content structure which contains a start screen, a menu and the main content pages and the quiz.

3.1.1. Methodology of structuring and organising a mobile learning application

Kerres [8] defines four categories to structure and organize a computer-aided and multimedia-based learning application:

- Exposition
- Exploration
- Construction
- Communication

A mobile learning application is a computer-aided and multimedia-based learning application too. Therefore it should fulfil as much of these four fields as possible to achieve a greater learning-richness. How these four categories can be realized within a mobile learning application will be covered in the following chapters.

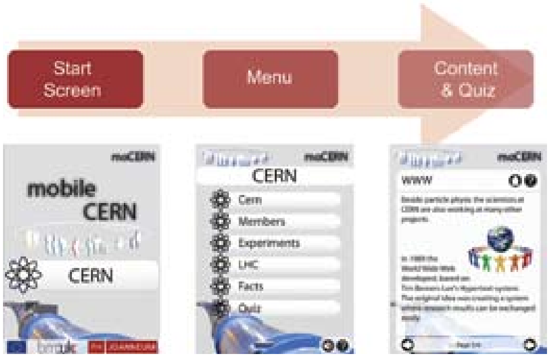


Figure 3. Application structure

Exposition - The field of the Exposition covers the learning objects as they are known from Computer Based Traings (CBTs) or Web Based Traings (WBT). The learning objects are characterised through a defined and sequential learning path. The learning matter is presented on a sequence of slides and concluded with a set of questions. These questions can either intent to check the knowledge of the user or to strengthen the newly achieved knowledge. The basic learning theory behind the Exposition is the behaviourism [8][9].

Learning objects for mobile learning (mobile learning objects - MLO) can be structured generally the same way as learning objects for eLearning. The main difference lies in the way of the presentation and the amount of information. Due the limitation of the screen size very little continuous text should be used. Instead different kinds of media should be applied. For example: figures and pictures, videos or audio and spoken text. Nevertheless a mobile learning object shouldn't contain as much information as an eLearning learning object. Therefore it is advisable to split a topic up into more mobile learning objects which are related but also independent to each other.

Another aspect that should be considered within the creation of a mobile learning object is the way of use. If a user goes through a CBT or a WBT it can be assumed that the user takes a certain amount of time and concentrates on the subject. With mobile learning there is a total different scenario, because it will be mainly used in idle periods. But these idle periods can end immediately [10].

For example a person waits at the bus-station and uses this time for learning on his mobile phone. Suddenly the bus arrives, so he has to stop to enter the bus. After he has seated he wants to continue learning till he arrives at the desired destination.

The learning object should be structured in such a way that the user can stop learning immediately and continue learning after a certain amount of time. This special kind of use requires the structure of the learning content in small and homogeneous "information nuggets". These information nuggets should fit to one page or slide. If the user stops immediately it should be possible to continue learning just by going through the last information nugget.

Exploration - Explorative learning means learning without a learning path. So the user can explore on its own the available learning content. A realisation for explorative learning would be a hypermedia system (networked multimedia-based content) and in the broader sense a knowledge system [8]. Explorative learning gives the responsibility and the power to the user. He can learn whatever he wants to learn and that usually increases the motivation for learning. Due the lack of a learning path, explorative learning is more suitable for users, who have already a basic knowledge and the skill for learning on their own. Whereas learning with learning object is more suitable for inexperienced users [8][11].

A main problem of explorative learning is the lost-in-hyperspace phenomena. If the navigation and the status information are insufficient, the user gets lost in the hypertext system. This leads to frustration and the possible end of learning.

Within the adaptation of a hypermedia system for a mobile learning application only the presentation of the content has to be considered. Due the small screen size the same problems occur within the exposition.

Construction - The area of construction can be described as “learning by doing” and are influenced by the learning theories of cognitivism and constructivism. Simulations and models are the main instruments for the Construction. The main problem with these instruments lies in the required processing power that is not available for Smart phones for now. Therefore a Simulation could just be realized by a thin-client system today. The solution would be that a server makes all the processing and calculations and the client (the Smartphone) displays the pre-processed results [8][9].

Communication - Communication is one main demand of constructivism and claims for synchronous and asynchronous communication instruments like: Chat, eMail, video and audio conference, fora, blackboard, etc. These instruments should help to build up relationships between the students and to the instructors. Students with a similar knowledge can discuss problems or simply ask a human teacher, no matter where the people are located. Also team-projects can be realized over these communication methods [8][11].

Instruments for communication are not a great problem on Smart phones, because the main features are already realized on the devices, like the ability for audio and video conferencing, SMS, MMS and eMail. An additional, suitable communication instrument would be a multimedia-forum with the ability to store recorded speech and videos. The input of text is not very suitable for a mobile phone, because the input needs lot of time. Therefore it would be easier to simply record the user’s voice and store it as a forum-entry.

3.2. Technical Aspect

For the technical aspect you have to think about to use the applications online in the web, or offline on your mobile device, or combined with a so called quick response code, which technology I will present later. To fulfil this we decided to develop the applications with a state of the art development kit, in our case Adobe Flash Lite for mobile phones.

Most of the modern mobile phones and smart phones are able to handle interactive Flash Lite content. There exists a detailed list of supported mobile devices at the website of the flash technology developer [12][13]. Also we have to optimize the file size for downloading.

The distribution of new mobile learning objects is done by a central internet server: the learning platform. There are all available learning objects hosted. If the user wants to use a new learning object he can download it right away from the server over a mobile website. If the learning object has once been downloaded, it can be used without a new connection to the server. Also the permanent download or offline installation to the mobile phone is possible.

3.2.1. QR codes

Sure you have already seen such Quick Response Code or short QR code (see Fig. 5), for example in the advertisement. With the mobile phone camera you take an image from the QR code and free software like i-nigma [14] or Kaywa [15] detects the code and interprets the information, like an internet link. In the case of our mobile applications the flash content will be downloaded.

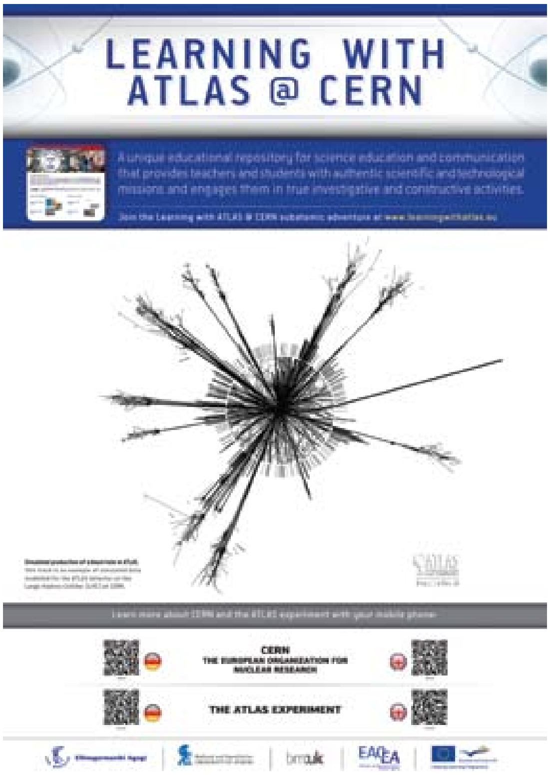


Figure 4. *Poster with QR codes*

One possibility is to place the QR code on posters for different topics and events as the "Learning with ATLAS@CERN" poster shown in Fig. 4. An enlargement of a QR code out of the poster, which leads to the ATLAS application in English [16] is presented in Fig. 5.

Figure 5. *QR code for ATLAS [en]*

3.3. Educational Content

For the educational aspect the information used needs to be short, precise and concise about very specific physical topics such as quantum physics. The content and programming structure were developed by students at the University of Applied Science of the FH Joanneum in Graz in the framework of a project work over a semester. The developed material has been screened through a quality control process involving professionals in this field of mobile technology, physics and learning.

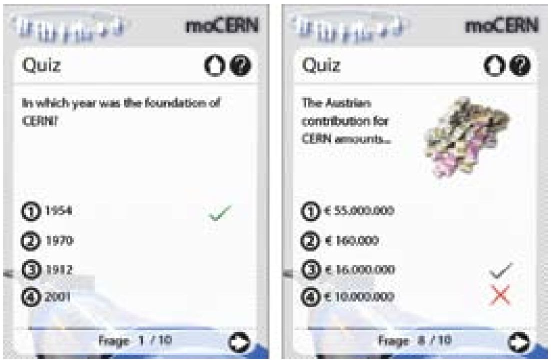


Figure 6. *Quiz for self assessment*

Make your own QR code with online QR code generators EasyTag [17] or GOQR.ME [18].

4. Conclusions

MoCERN combines the popularity of mobile devices with an educational objective. Using such an application can provide an additional stimulus, incentive to learn. The integration of such technology within a pedagogical framework has the potential to increase the students' motivation to learn and in this particular instance increase the students' understanding and willingness to study high-energy physics. The framework adds purpose and structured diversity to the learning scenario for students with structured inquiry and social collaboration as well as acting as a springboard for further in-depth learning. Similarly for teachers the framework places technology use within a learning context and allows teachers the opportunity to rationalise the use of technology and gain confidence with it.

The mobile applications of moCERN are a learner centred approach, so the learner determines his learning effort. To introduce the mobile applications into the classroom, they are implemented in some "Learning with ATLAS@CERN" learning missions. The applications should not replace alternative learning resources, but complement them as they form part of a learning sequence in a collaborative and constructivist environment..

The use of mobile technologies is a complementary way for students to retrieve and process information. Utilising technologies that students are so familiar with broadens the available learning possibilities within an educational platform and so learning gets more flexible anywhere and anytime.

5. Acknowledgements

We acknowledge our project colleagues, Also many thanks to the supporting team of the department IT/3 of the BMUKK (Federal Ministry for Education, Arts and Culture) as well as the department Information Management of the FH Joanneum, Graz, and the involved students.

6. References (and Notes)

[1] "Learning with ATLAS@CERN" portal: http://www.learningwithatlas-portal.eu/

[2] moCERN mobile applications online [en]: http://www.learningwithatlas-portal.eu/en/node/93580

[3] moCERN mobile applications online [de]: http://www.learningwithatlas-portal.eu/en/node/93579

[4] Attewell, J. (2005). From Research and Development to Mobile Learning: Tools for Education and Training Providors and their Learners. Paper presented at the 4th World Conference on mLearning.

[5] Cochrane, T. (2005). Mobilising learning: A primer for utilising wireless palm devices to facilitate a collaborative learning environment. Paper presented at the 22nd ASCLITE conference, Brisbane 4-7 December.

[6] Kulkuska-Hume, A., Traxler, J., and Petit, J. (2007). Designed and user-generated activity in the mobile age. Journal of Learning Design. 2(1), pp. 52-65

[7] Caballé, S., Xhafa, F., and Barolli, L. (2010). Using mobile devices to support online collaborative learning. Mobile Information Systems. 6(1), pp.27 – 47.

[8] Kerres, M. (2001). Multimediale und telemediale Lernumgebungen. Konzeption und Entwick-lung, zweite vollständig überarbeitete Auflage, Oldenbourg Verlag München, ISBN: 3-486-25055-8

[9] Dick, Egon (2000). Multimediale Lernpro-gramme und telematische Lernarrangements Einführung in die didaktische Gestaltung, BW Bildung und Wissen Nürnberg, ISBN 3-8214-7019-4

[10] Venkatesch, Viswanath; V. Ramesh, Massey, Anne P. (2003): Understanding Usability in Mobile Commerce; Dezember 2003, Communications of the ACM, Vol 46, Seite 53-56

[11] Schulmeister, R. (2002). Grundlagen hyper-medialer Lernsysteme. Theorie - Didaktik – Design, dritte korrigierte Auflage, Oldenbourg Verlag München, ISBN: 3-486-25864-8

[12] Flash supported devices http://www.

adobe.com/mobile/supported_devices/handsets.html

[13] Flash supported devices list http://www.adobe.com/mobile/pdfs/flash_lite_forecast_installed_base_jan09.pdf

[14] i-nigma: http://www.i-nigma.com/

[15] Kaywa: http://reader.kaywa.com/

[16] ATLAS application in English: http://www.learningwithatlas-portal.eu/2010_04_moCern_website/03_en.swf

[17] EasyTag: http://easytag.fh-joanneum.at/

[18] GOQR.ME: http://goqr.me/

The LHC adventure

Michael Koratzinos
CERN,
1211 Geneva 23, Switzerland.
mike@cern.ch

Abstract

The large hadron collider – LHC – is the flagship facility of CERN, the European Organization for Nuclear Research, situated in the Franco-Swiss border near Geneva. Together with its particle physics detectors, it is the most complicated scientific instrument ever constructed. Bigger than anything that CERN has built before, it is full or superlatives and world firsts: The lowest temperature large-scale installation (27 kilometres of magnets at -271o C); the highest energies (7TeV per proton beam); the highest data rates (near-GigaHerz collision rates per experiment); the largest scientific detectors ever built by the largest scientific collaborations.

The LHC project, apart from its indisputable excellence in science, provides a lot of opportunities for the general public to share this unique experience through a sizable outreach program that includes guided tours of the facilities – experiments, machines, infrastructure and test halls.

During the presentation in Hsci 2010 some of the key issues of this large project concerning the machine were discussed with emphasis on the human element going through the inevitable highs and lows of such a project. These proceedings can only elucidate part of this presentation.

Keywords

CERN, LHC, outreach, visits.

1. Introduction to CERN

CERN (still known from the acronym of the provisional body created in 1952 with the mandate of establishing a world-class fundamental physics research organization in Europe Conseil Européen pour la Recherche Nucléaire) is the largest laboratory for particle physics in the world today. It was founded in 1954 by 12 member states (including Greece) and today numbers 20 member states, six observer states and about 30 states with collaborating agreements. It has about 2300 staff members and in excess of 10000 users, mainly university scientists that collaborate with one of the experiments taking place at CERN. As time passes, CERN breaks the confines of Europe to become more and more a world laboratory.

2. Introduction to the LHC

The LHC is the latest of a series of large projects at CERN. Together with its detectors, it is the most complex scientific machine ever constructed. The first studies on the LHC started in 1982. In 1994 the LHC was approved in principle by the CERN council, and in 1996 the final decision was taken to start construction. The installation of components in the LHC tunnel (previously housing the LEP accelerator) started in 2003, and in 2005 hardware commissioning commenced. The first protons circulated around the ring in 10 September 2008, whereas an accident nine days later stopped the project as the necessary repairs were carried out. In 2010, the first physics results have been presented at international conferences.

2.1 The magnetic systems

One of the key components of the LHC is the very powerful magnetic systems: There are 1232 magnetic dipoles are installed in the tunnel, each being about 15m long and weighing about 35t. Together with the 424 main quadrupoles, they have a maximum operating current of close to 13kA. To allow for such high currents, superconducting cables are used and the temperature of the magnets in the arcs is kept to a very low 1.9K, lower than the temperature of outer space. To sustain such low temperatures, two cooling systems are in operation: the first is a 4.5K Helium cooling system and the second a 1.8K helium cooling system, operating at 15mbar. The second system cools the bulk of the helium from the 4.5K system, through a heat exchanger traversing each magnet, bringing its temperature below the lambda point of Helium (about 2.1K) so that the Helium in the magnets becomes a superliquid. Superliquid Helium has very good heat conduction properties and it is ideally suited for the job of keeping the magnets cold. Huge cryogenic installations are needed to keep the magnets at such temperatures, and the cooling down of the whole accelerator takes many weeks.

2.2 Machine protection

The total inductance of the high current circuits of the LHC and the operating currents are large. As a result, a lot of energy is stored in the LHC magnets during operation (9GJ at top beam energy – equal to the kinetic energy of an 80,000 t aircraft carrier sailing at 35 knots). Such amount of energy needs an efficient detection system to detect problems as early as possible and a robust extraction system in case a problem is detected and energy needs to be extracted as quickly as possible. In spite of such systems, an undetected bad superconducting cable joint gave way during a high current test on 19 September 2008, resulting in an extended down period for the accelerator for the resulting damage to be repaired and for consolidation measures to be taken.

The two counter-rotating proton beams also carry a lot of energy (each proton having an energy roughly equal the kinetic energy of a mosquito and the whole beam that of a speeding train). A dedicated system with thousands of sensors (termed Beam Position Monitors, BPMs) measure the beam position along the ring and another system measures eventual losses using loss sensors (termed Beam Loss Monitors BLMs). In case beam losses are detected above a predefined threshold, the beam is diverted within a very short period of time to a dedicated beam dump area. The machine protection systems have the difficult task of needing to be efficient and at the same time have the minimum amount of false alarms that result in accelerator down time.

3. The LHC start-up

The startup of such a facility is a multi-faceted exercise and a large number of people contributed to making it a success.

Prior to the startup, all systems needed to be commissioned individually in situ through a series of tests. As an example, the electrical circuits of the LHC are about 1700, each needing up to 20 tests to qualify. Commissioning of the LHC systems started in 2005 and was completed to a very large extend in 2008 just in time for the first circulating beams, scheduled for 10 September 2010.

10 September 2008 was a big media day at CERN, with 250 invited journalists and 30 television stations from all over the world. The number of viewers of the event was in the millions. What made the day more remarkable was that we attempted to do something for the first time, live, with absolutely no guarrantee of success: The idea was to send a clockwise and then an anti-clockwise beam of protons in the LHC and obtain at least one revolution. Everything worked beaurifuly and the day was a complete success for CERN.

Unfortunately, nine days later, during a programmed test of one of the circuits that was not yet commissioned to its nominal working parameters (the last one in fact), disaster broke: The LHC has about 10000 high-current superconducting cable joints – all soldered in situ in the tunnel. One of these connections was defective and there was a rupture of this joint while there were 600MJ of energy stored in one sector fo the machine. 70% of this energy was dissipated in the tunnel, first fuelling electric arcs and vaporizing material, and then, when there was a rupture of the insulation vacuum of the magnets, due to the large forces present, moving magnets off their feet and into their neighbours. In total, 50 magnets had to be replaced and the vacuum pipe repaired and cleaned up. Forteen months later the LHC was ready for the next step.

On 20 November 2009, the LHC saw circulating protons again, whereas 10 days later the first collisions at 1.2+1.2TeV were recorded. This represented a new world energy record, taking the record from Fermilab in the United States that held it for quite a few years.

On 30 March 2010 the first 3.5+3.5TeV collisions were recorded, the maximum energy scheduled for 2010. Since then, records in luminosity came in quick succession: 19 April: an order of magnitude increase in luminosity; 22 May: another order of magnitude in luminosity, now with 13 proton bunches per beam; 26 May: proton bunches get their design intensity of 10^11 protons. The latest luminisity record was on 14 October, where the luminosity barrier of 10^32 was broken. This is just two orders of magnitude from the design luminositiy of the machine.

It has been a bumpy, intense, but ultimately very satisfying ride.

4. CERN visits

One of the missions of CERN is education. And apart from educating the scientists of tomorrow, CERN also is also keen to inform the general public on what happens at CERN and especially keen to inspire the young generation. The general public is able to visit CERN (by filling a simple form on-line) and a dedicated service, the CERN visits service, is in charge of the logistics of their visit. People are shown around in groups, after first being introduced to CERN and particle physics by an hour-long talk. The itineraries of the visits change with time as a function of current interest and availability: some years ago, the most popular itineraries were the experimental caverns where the huge LHC experiments are housed. Today, as the LHC tunnel is closed, they have been replaced by the LHC magnets test facility and the CERN control room. All guides and speakers are volunteers from the CERN scientific community.

Over the years the number of visitors to CERN has increased. A few years ago 20,000 people visited CERN every year. The latest statistics show that more than 50,000 visitors came to CERN during the last year.

The number of visitors per population of 100,000 per member state can be seen in fig. 1 for the period 1 January to end of July 2010 (seven months).

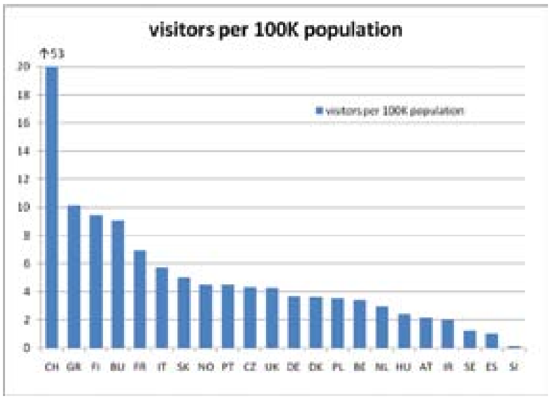


Figure 1: *number of visitors at CERN during the period 1 Jan 2010 to 24 July 2010, per nationality per population of 100,000*

Switzerland, one of the two host states, has the most visitors per capita (more than 50 per population of 100,000), many coming from the immediate vicinity of CERN, the Geneva region. Greece is in the top three countries with about 10 visitors per population of 100,000 in this (7 month) period, even above one of the host countries, France. Last year, the number of visitors from Greece was close to 2000.

5. Acknowledgements

I wish to thank the organisers of Hsci2010 for their invitation and hospitality. This work would not have been possible without the hard work and dedication of numerous colleagues at CERN who managed to get underway the largest scientific instrument ever designed.

Educational Scenarios for University Students based on the ATLAS experiment and related Outreach activities

P M Watkins
School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK
P.M.Watkins@bham.ac.uk

Abstract

It is very useful to introduce some of the techniques used in experiments, such as the ATLAS experiment at the Large Hadron Collider (LHC) at CERN, into University physics undergraduate and graduate courses. This material is frequently introduced into University lecture courses but there are less resources that can be used in Physics laboratories alongside more traditional laboratory experiments. This article discusses some new scenarios that have been developed and tested in University Physics laboratory classes. These use both collision and simulated data from the ATLAS experiment at the LHC and were developed as part of the Learning with ATLAS at CERN EU outreach project.

These scenarios use the Minerva software tools to visualise data from the ATLAS detector. This visualisation software is the same as used by ATLAS physicists for their detector monitoring and physics analysis work. A few of the more complex options are hidden by using customised configuration files to make it easier for non specialists to use.

In these projects Minerva can be used to help select and classify proton-proton collisions which produce different types of final state particles. For example proton-proton collisions where W or Z bosons are produced are most easily identified by the presence of very energetic electrons or muons. The W or Z boson decays very quickly, effectively at the collision point, and the electron or muon decay products typically have very high transverse momentum. One of the decay products of the W boson is an energetic neutrino which does not leave any signals in the detector. However its presence and its transverse momentum can be deduced using momentum conservation.

Once students have selected collisions containing energetic electrons, muons or neutrinos then they can use a relativistic equation to calculate the mass of the boson candidate. This scenario was used in the first year undergraduate laboratories in the School of Physics and Astronomy, University of Birmingham during Spring 2010 and received very encouraging feedback from the students.

In 7 TeV collision data recorded at ATLAS, collisions produce on average thirty charged and neutral particles. In many of these collisions neutral kaon particles are produced which decay via the weak force into two charged pions. This decay is visible in the ATLAS tracking detector and can be visualised by Minerva. The University of Stockholm has developed a scenario to study the properties of these kaon decays in the early collision data. Using the same relativistic equation, the mass of the kaon can be calculated and the effect of the relativity on its lifetime can also be studied In this early phase of LHC running this scenario has the advantage that it uses collision data whereas for the moment the W and Z boson studies are based on simulated collision data.

We have also used the wide interest in the LHC to organise a number of different competitions at the University for schoolchildren. These have included competitions where short videoclips on Particle Physics topics are submitted which are designed to be effective for different age groups. This enables small groups of schoolchildren to work together on a project inside and outside the classroom without requiring very much assistance from the teacher.

Another very popular competition is where small groups of children produce a powerpoint presentation and demonstrations for a particular age group. In this 'Cascade' competition the group presents a 15 minute talk in their own school and the most successful teams are invited to a grand final at the University. Again the focus is on providing the opportunity for children to learn more about the subject and develop the skills needed to work in a team to deliver a presentation.. The major prizes provide support for the winning teams to visit CERN. These groups often come up with very innovative presentations well matched to a younger audience.

Keywords

ATLAS, LHC, Minerva, W boson, Z boson, strange particle, Cascade competition

1. Introduction

Many people are very interested in the Large Hadron Collider (LHC) project at CERN [1] which is now producing the highest energy proton-proton collisions seen at any accelerator. We have developed a wide range of Outreach projects to try to benefit from this interest and provided educational resources that can be used in a range of different environments and for different age groups. In this article we describe a few of these. We first briefly introduce the particles that we will be studying and how they are recognised in the massive ATLAS [2] detector at the LHC. Then the Minerva software package is introduced which visualises the collisions and is used by students to identify different types of particles produced in the collisions. Many particles have very short lifetimes and only their decay products are seen in the detector. We then outline how the presence of W or Z bosons in a particular collision can be deduced. These ideas are useful in all searches for new particles at the LHC including the Higgs boson (Fig 1). The Minerva package [3] has been used extensively in a range of Particle Physics Masterclasses and is also available for individual use by students or their teachers. A new application that we have developed for an undergraduate first year physics laboratory is briefly described. Finally a few LHC related outreach projects that have been developed in the School of Physics and Astronomy at the University of Birmingham are described.

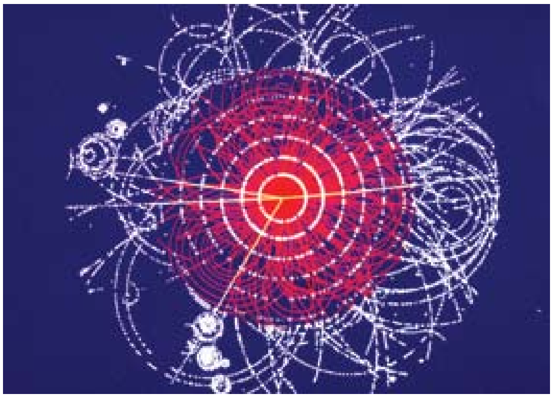


Figure 1. *Simulation of a collision in the ATLAS detector in which a Higgs boson decays to four energetic leptons*

2. Recognising Particles with the ATLAS detector

The LHC proton beams collide head on at the centre of the ATLAS detector. All the particles produced in the collision travel away from the collision point and are detected in the various layers of the detector. There are many different layers which are used to identify each particle produced in the collision and to measure their momentum and charge.

The fundamental quarks and leptons of the Standard Model of Particle Physics are shown in Fig 2.

The charged leptons can be observed in the ATLAS detector but the neutrinos escape from the detector without interacting. Quarks are never observed alone but only in hadrons which are made from two or three quark or antiquark combinations. Hadrons including the proton, pion and neutron can be detected and measured in the ATLAS detector. The direction and energy of an energetic quark or antiquark from the collision can be deduced from the properties of a stream of nearby hadrons known as a jet. The force carriers are also detected in various ways when produced in a collision. The photon can be detected directly whereas gluons are indirectly detected as a jet of hadrons with similar properties to a quark jet. The massive W and Z bosons decay before they can be directly detected but can be indirectly observed through their decay products as discussed later in this article.

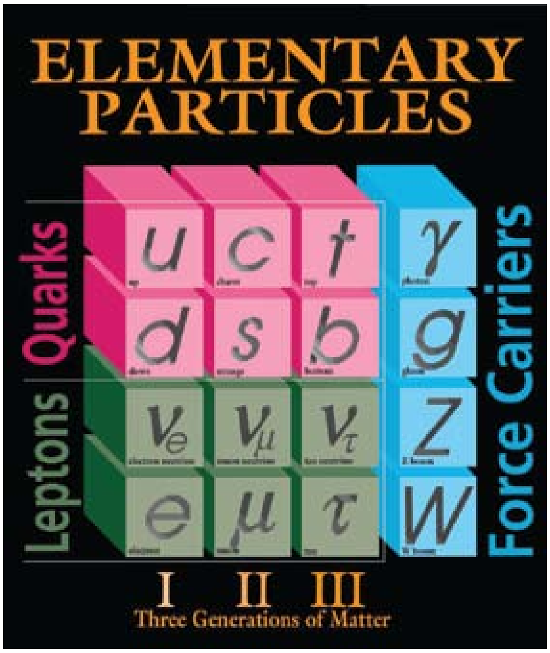


Figure 2. *The fundamental constituents and force carriers of the Standard Model of Particle Physics*

The layers of the ATLAS detector comprise the tracker, electromagnetic then hadronic calorimeter and finally the muon detector. The tracker detects charged particles through ionisation in detectors along their path and the track curvature in a solenoidal magnetic field is used to calculate the particle charge and momentum.

The calorimeter layers are used to measure the energy of both charged and neutral particles. The calorimeter has a large number of detector layers sandwiched between alternating absorber layers. Particles interact and produce secondary particles which are counted by their ionisation in the thin detector layers. The number of secondary particles is related to the energy of the incident particle and so this energy can be estimated. In addition electrons and photons deposit their energy much earlier in depth than hadrons and this is used to identify electrons or photons which deposit all their energy in the electromagnetic calorimeter.

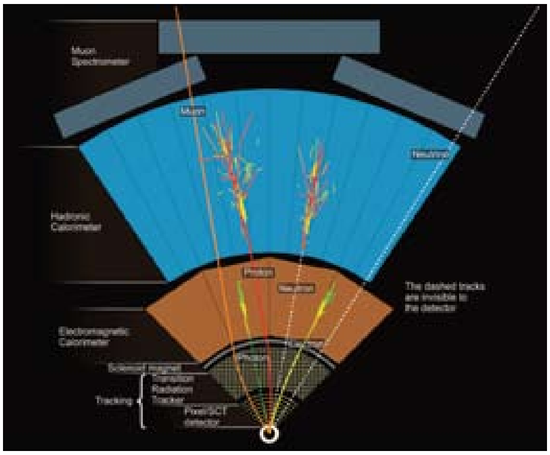


Figure 3. *Summary of how different types of particles deposit their energy in the layers of the ATLAS detector*

The muon is a very penetrating particle and leaves a small signal in all the detector layers including the outer muon detector. A neutrino rarely interacts and is not detected in any layers but its presence can sometimes be detected using momentum conservation. Even the most hermetic detector must have gaps for the beam pipe and so only the transverse momentum and not the full momentum can be deduced by this method. Fig 3 summarises how the different particles deposit their energy in the layers of the ATLAS detector.

As the proton contains quarks and gluons many collisions are expected to produce energetic quarks and gluons. Single quarks or gluons carry colour charge and neither have been detected alone. The strong force between quarks and gluons generates other quark-antiquark pairs. When an energetic quark or gluon is produced in the detector we observe several hadrons moving in the same direction as the original quark or gluon which is called a jet. If the hadron contains a b quark then the hadron decays after typically 10-13 s and some of the decay tracks will be displaced from the collision point. Identifying jets with these displaced tracks is called b –tagging and this can be very important in some of the collision measurements.

In summary we now have the tools to identify the particles produced in a collision. The most interesting collisions produce particles with high transverse momentum as a result of a very energetic collision between the constituents of the protons or from the decay of a massive particle. For the exercises mentioned here we just need to recognise electrons, muons, and neutrinos.

3. Identifying particles with Minerva

Each collision recorded by the ATLAS detector contains an enormous amount of data. Visualisation packages are very useful as they can display this data in a form that makes it easier to isolate detector problems and to highlight which particles have been produced in the collision. The Atlantis visualisation package is used by physicists for both of these tasks and is a key feature of detector monitoring in the ATLAS control room.

The Minerva outreach package makes use of Atlantis software but simply uses modified configuration files to exclude some of the more technical displays and make it easier to use for outreach purposes.

A screenshot of Minerva is shown in Fig 4. This shows the canvas where three different views of the collision are typically shown. The lower image is a side view of the detector with the collision point at the centre. The top image on the left shows the detector as viewed from the beam line. The image on the top right indicates where the energy is deposited in the calorimeter in a view where the cylindrical surface of the calorimeter is shown as a flat surface. It is possible from the information shown in these three views to identify all the particles with large energy produced in each collision.

The web-based Minerva package (http://atlas-minerva.web.cern.ch/atlas-minerva/) includes some introductory material to explain what is shown on the screen and some test events that users can study to gain experience. We have also included a number of other data files containing samples of simulated collisions which include W and Z bosons and other 'background' processes.

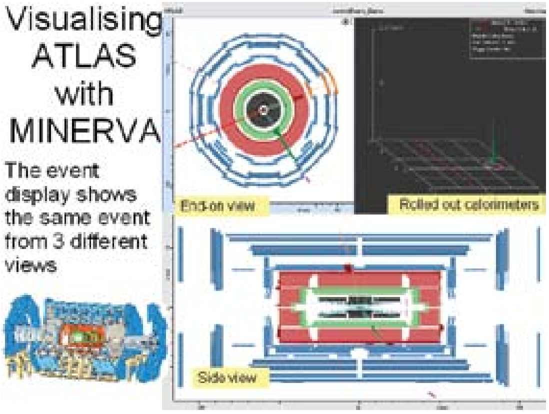


Figure 4. *Screen shot of the Minerva event display which is used to visualise the products of a proton-proton collision in the ATLAS detector (see text for details)*

We have used Minerva in a range of outreach events including Particle Physics Masterclasses

for several years now and updated it using the feedback from such events. Two of the largest Masterclasses were held at the Rutherford Appleton Laboratory and the University of Birmingham in the UK and some pictures from these events are shown in Fig 5.

Figure 5. *Particle Physics Masterclass events at Rutherford-Appleton Laboratory and the University of Birmingham using Minerva*

The Masterclasses are usually held at a University or Research Centre where there are many experts on hand to help the students. However we have also set up another version so that it can be used more easily by individual students or their teachers. In this case we have included all the support documentation on the web. Both versions are accessible from the Minerva web page.

4. Making sense of collisions

When we observe an energetic lepton after a proton-proton collision it has usually been produced by the decay of a high mass particle. If the massive particle decays into two leptons then these will be emitted back to back if the parent particle was at rest. However at the LHC this is unlikely as it is the quark and gluon constituents of the proton that are colliding and these usually have different momentum. This means that the decay leptons are usually produced with large transverse momentum but they are not back to back.

Imagine we observe two energetic leptons with opposite charges amongst the many particles produced in the collision. How can we tell if they are the decay products of a massive short-lived particle?

We can use the relativistic equation which is rather similar to the universally known $E=mc^2$! The equation is $E^2 = P^2c^2 + M^2c^4$ where E is the energy, p is the momentum, M is known as the invariant mass and c is the speed of light. If the two leptons are the only decay product from a massive particle then we can add their energies to get the energy of the decaying particle. Similarly we can add the vector momenta of the two particles to obtain the momentum of the parent. As we now have E and P we can rearrange the equation and calculate the invariant mass M. If it was a Z boson decay this calculated value M should be consistent with the Z boson mass.

This is how we search for short-lived particles at a collider. For example we study a number of collisions containing pairs of energetic leptons with opposite charges. We repeat the calculation for each event and produce a histogram of the mass M for all these events. If we find a clear peak in this mass histogram then this probably indicates that a short-lived particle was produced in many of those collisions and its mass can be determined from the position of the mass peak. In any real experiment there will be measurement errors and the peak will be broadened because of these errors.

However imagine a perfect experiment with no such errors or incredibly small errors. How would the mass peak for a short-lived particle appear in this case? The Z boson has a very short lifetime of around 10-24 s and in the quantum world this means that Heisenberg's uncertainty principle is important. We cannot know the precise value of a particle's energy at a precise time. If the lifetime is very short then there must be an energy uncertainty and so the mass peak would be broadened even in a perfect experiment! In fact the width of the peak can even be used to measure the particle's lifetime.

5. University Laboratory experiments

As you can see from the previous section there are many ways of building more complex projects around the identification of LHC collisions products with the Minerva package. Many of these extensions lead naturally into Quantum Mechanics and Relativity where it is often difficult to design simple laboratory experiments.

We have used some of the ideas discussed in this article to design an experiment for the first year undergraduate Physics laboratory at the University of Birmingham. This was developed and stored as educational content in the Learning with ATLAS portal [5] and was used for the first time by many pairs of students in the Spring term 2010.

Many of the concepts that are met in standard practical experiments are also experienced in this project. When measuring and comparing the rates of production of W and Z bosons or their branching ratios for decays into electrons and muons it is important to quantify the errors on the measurements using basic statistics.

Although the collisions can be distinguished without understanding the details of each detector the use of a current collider experiment provides a direct link into the technologies used in leading edge detectors in the field. The interpretation and discussion of the shapes of the invariant mass histogrammes provide an excellent opportunity to relate this to Heisenberg's Uncertainty principle and Relativity.

As soon as the recently acquired collision data from ATLAS is made available outside the collaboration it will be added into the Minerva data files and also made available for use in any of these exercises.

6. LHC related outreach competitions

We have also used the wide interest in the LHC to organise a number of different competitions at the University for schoolchildren. These have included competitions where short videoclips on Particle Physics topics are submitted which are designed to be effective for different age groups. This enables small groups of schoolchildren to work together on a project inside and outside the classroom without requiring very much assistance from the teacher. One of the web pages used to advertise this competition is shown in Fig 6. Details of the competition can be found at http://www.hep.ph.bham.ac.uk/VideoAnimationCompetition/Welcome.html

Figure 6. *Web page used to advertise a LHC related video/animation competition*

Another very popular competition is where small groups of children produce a powerpoint presentation and associated demonstrations for a particular age group. In this 'Cascade' competition the group presents a 15 minute talk in their own school and the most successful teams are invited to a grand final at the University. Again the focus is on providing the opportunity for children to learn more about the subject and develop the skills needed to work in a team to deliver a presentation.. The major prizes provide support for the winning teams to visit CERN. These groups often come up with very innovative presentations well matched to a younger audience.

We have organised several versions of this 'Cascade' competition over a number of years. In the first year we ran a regional competition and visited schools to select the best teams. A photo of the winning team from that first competition is shown in Fig 7.

Figure 7. *Winning team in the first ever 'Cascade' competition from King Charles School in Kidderminster*

In later years we had entries from all parts of the UK and selected the most promising teams from videos of their performances. We invited the best teams to a finals event at the University of Birmingham to select the major prize-winners. Much more information about the competition can be found at http://www.hep.ph.bham.ac.uk/cascade/

7. Acknowledgements

I gratefully acknowledge the support of many staff and students from the Particle Physics group at the University of Birmingham for their help in this work particularly in contributing to a range of Outreach events where these ideas have been tested. I have also benefited from many fruitful discussions with my ATLAS colleagues on the Learning with ATLAS project.

I would also like to thank all my colleagues from the Minerva team (Tom McLaughlan, Mark Stockton and Monika Wielers) for their work on this project.

Finally I would like to thank my colleague in the School of Physics and Astronomy at the University of Birmingham Lynne Long for her unstinting efforts to make these Outreach projects a success.

8. References

[1] CERN website: http://www.cern.ch

[2] ATLAS public website: http://atlas.ch/

[3] MINERVA website: http://atlas-minerva.web.cern.ch/atlas-minerva/

[4] ATLANTIS website: http://www.hep.ucl.ac.uk/atlas/atlantis/

[5] The Learning with ATLAS web portal: http://learningwithatlas-portal.eu/

Science Center To Go A Mixed Reality Learning Environment of Miniature Exhibits

Hagen Buchholz, Constantin Brosda, Richard Wetzel
Collaborative Virtual and Augmented Environments, Fraunhofer FIT
Schloss Birlinghoven, DE-5374 Sankt Augustin - Germany , +49-2241-142688
{hagen.buchholz, constantin.brosda, richard.wetzel}@fit.fraunhofer.de

Abstract

Modern science museums deliver exhibits that involve visitors in sessions of active playful learning. Mixed Reality may additionally be used as a catalyst for science centre exhibits to provide new perspectives and reveal otherwise hidden phenomena. Such sophisticated exhibits might well be qualified for improved learning at school – except they are hardly available outside of science centres. Our approach addresses this challenge by bringing miniaturized Augmented Reality exhibits out of the science centre into schools. The presented miniature exhibits uncouple science centre exhibits from their traditional venue and deliver natural ways of learning whenever and wherever it is desired. Therefore a set of miniature exhibits has been designed with the ambitious goal to meet the requirements of nowadays school curriculums. In this paper a science centre in a suitcase will be presented and discussed offering tailor-made learning experiences augmented through normal computers.

Keywords

Augmented Reality, Mixed Reality, Learning, Tangible User Interface, Science Museums

1. Introduction

The main idea of modern science centres or science museums has already been expressed in the following old Chinese saying: “Tell me, and I will forget. Show me, and I will remember. Involve me, and I will understand”. Usually a museums visitor is passively looking at museum exhibits advised not to touch any objects. In modern science centres, on the other hand, visitors become an active part of each exhibit and get involved into experimental learning sessions. Such an active involvement demands sophisticated exhibits which work on many levels. Each exhibit is especially designed providing a new perspective on a subject. This perspective is created through interaction with the exhibit and usually addresses multiple senses. In the EU-Project CONNECT such hands on science centre exhibits have been extended through Augmented Reality (AR) to virtually show phenomena which are hard to implement in real models.

The main idea of CONNECT was the integration of science centre visits into the school curriculum. Adaptability of learning content and remote participation are both key factors of CONNECT. On the one hand a science centre visit is time consuming and relatively expensive for school classes. On the other hand, it is very challenging to integrate given exhibits into the curriculum. The CONNECT platform provides a solution for both of these challenges. The virtual AR content can easily be adapted to the school curriculum via a web interface, and an audio-video stream allows for distant participation of classmates. However, such a remote connection does not transport the full hands on experience of the real science centre – the accessibility of science centre learning is basically still limited to a live video broadcast. [1] [2]

In EXPLOAR, the follow up project of CONNECT, this platform has been evaluated in detail and its AR component has been revised. As part of the revision the problem of limited accessibility has been tackled by the development of a miniaturized version of one of the AR exhibits. First tests of this so called "Science Center To Go" seemed promising and lead to a new project called SCeTGo for further refinement and detailed evaluation. Within the SCeTGo project a suitcase full of miniature exhibits is being developed and evaluated. The project focuses on a direct integration into the school curriculum to further bridge the gap between science centres and learning in schools.

In the following, we will present the concept and first prototype of this system. After taking a look at related work in section 2, we will give a more detailed overview of our concept in section 3. In section 4 we describe the first set of miniatures of the Science Center To Go suitcase before we discuss our findings and future work in section 5.

2. Related Work

As previously mentioned, the Science Center To Go is based on work of several consecutive projects. Its basis has been set in CONNECT, which brought Augmented Reality into science centres to create novel learning possibilities [2]. Rich mixed realities learning experiences were created by enhancing real exhibits with virtual content. A web platform enabled teachers to adapt learning content to the school curriculum and give access for distant learners [1].

In the project EXPLOAR the existing CONNECT system has been extended and the idea of the Science Center To Go was born to bring the full hands on learning experience outside the science centre. The first miniature exhibit called the MiniWing has been developed and went through first evaluations and iterations of refinement. While the CONNECT AR-component build on expensive sensors and highly sophisticated setups Science Center To Go aims for increased accessibility through optimized simplicity. A key aspect of the Science Center To Go is to target a broader audience and ideally hit a mass market, therefore only off the shelf hard and software is being used. [3]

CONNECT, EXPLOAR and SCeTGo are examples of AR based learning support with a high emphasis on physical interaction. On the other hand numerous AR based tools for learning have been developed and investigated, where less emphasis was put on the physical interaction model, e.g. the Spinnstube® [10] or the Protein Magic Book [11].

Tangible User Interfaces (TUI) were first introduced by Ishii & Ullmer [4]. They seek to integrate computing power into everyday live by connecting physical objects to computers. Virtual digital functionality is assigned to real physical objects in order to achieve a more intuitive and effective way of interaction. TUIs built on the advantages of multi-sensorical interaction.

Ullmer and Ishii [5] state that an interaction device has a digital and a physical representation. When the electric power of an interface is removed the digital representation disappears and the physical representation remains. They further say, that “[t]angible interfaces are products of a careful balance between these two forms of representation.” ([5], p. 3)

Science centres demand hands on playful learning. We are building on Tangible User Interfaces to deliver a broad experience and lower the burden for learning while improving usability.

Following constructivistic ideas Resnick et al. [6] introduced Digital Manipulatives, which put emphasis on learning with physical objects. The basic concept is the integration of computational and communications capabilities in traditional children’s toys. Information technology is implemented into toys for playful and experimental learning. The idea mainly focused on extending toys in a way that they can be programmed. Therefore, programmable bricks, so called “crickets” where embedded into different kind of toys. These could be programmed, and even communicate with each other via infrared. As an example a common ball is equipped with a color LED, an accelerometer, and a programmable brick. The cricket could then be programmed to react on different ball movements detected by the accelerometer, and, thus mimic its “mood” by displaying it through a changing glow.

If we have a look at the entertainment and toy market, there are several popular products that invite children - and interested adults - into exploring science. Experimental kits like the ones produced by KOSMOS [7] have been on sale since the early 20th century. With these, children acquire a set of test-tubes, jars, petri dishes, liquids, acids and other chemical elements and can conduct their own experiments at home.

A similar approach is undertaken by Lego with their so-called Mindstorms [8]. These extend the normal Lego blocks by adding motors, cameras, sensors and even a mini computer to the mix. This computer can be programmed by the users and enables them to build a variety of different creations which typically resemble simple robots [9]. By using Lego Mindstorms children take first steps into programming. The usage of light or temperature sensors on the other hand enables them to learn about other traditional physics topics.

3. Concept Evolution

The concept behind the development of AR science centre exhibits started off fairly simple by extending existing exhibits visually. In the beginning the “magic” of AR was simply enough to create added value and enhance the experience. Over the past projects and evaluations this “magic” gave way to actual usage. The concept had to be refined iteratively to meet new upcoming requirements of miniature exhibits designed completely from scratch. The design of the required software and tangibles goes hand in hand and has to be considered thoroughly.

In contrast to many other AR-Learning environments Science Center To Go miniatures built on common hardware, without any sophisticated processors, in- or output devices. The minimal hardware requirements comprise a screen, webcam, and a pointing device. The only main interaction device should be the physical model of the miniature – the miniature as a TUI. AR is achieved by using the Magic Lense metaphor [12], where a rear camera image is shown on the screen superimposed by computer generated virtual content. If the camera is pointed towards the user one might also call it Magic Mirror [13].

By building on the Magic Lense metaphor and Tangible User Interfaces co-located cooperation is fostered since multiple users are able to look at the same screen and manipulate the miniature simultaneously.

When designing a miniature AR exhibit one should also be aware of the spectrum of possible exhibits. We are now able to distinguish three types of exhibits: traditional exhibits without AR, exhibits enriched through AR (Hybrid AR exhibits), and TUI based AR exhibits (Exclusive AR exhibits).

In most cases an exhibit in a science centre is a physical installation that facilitates a comprehensive learning experience by modelling a new perspective through interaction. Thus, the creation of such installations demands great deals of engineering, structural, and logical complexity.

An exhibit for learning about Bernoulli's effect, for example, could consist of a simple wind tunnel, a turbine, and a model of an airfoil. The airflow might be indicated through particulates of fine mist of liquid sprayed into the tunnel. The learner would be able to physically manipulate certain parts of this model and directly see the changes.

Augmented Reality technology might now be used to enrich the experience of a common exhibit even further, and feature phenomena which are impracticable to present with real models. Giving the example of the airfoil, an AR system could additionally visualize the lift force, different areas of air-pressure, or stresses exerted to body parts. Therefore, the computer system needs to track the position and orientation of the wing and the velocity of the stream created by the turbine. The tracking data is passed on to a computer simulation model which creates virtual output data, such as the lift force. The virtual output is after all presented to the user on the screen.

Taking the virtualization even further leads us to Exclusive AR exhibits. Such exhibits work completely without any real simulation. The physical representation only serves as a tangible input medium or a TUI. The rest of the simulation and the output is computer generated. Such a system offers highest flexibility in order to adapt learning content. It also reduces the physical complexity of the exhibit, and thus lowers the barrier for being massively produced. However, the key challenge hereby lies in preserving a comprehensive learning experience as it is provided by a real exhibit.

Taking the airfoil example; in comparison to the hybrid AR exhibit, one could even remove the turbine and particles of fine mist and use computer graphics to visualize the airflow. In this case, the mechanical complexity of the physical representation was reduced to a simple wing rotating around an axle, which itself does not give much room for experimenting and experiencing Bernoulli's characteristics. All simulation and feedback were computer generated, allowing users to experiment with the airfoil model and see how this changes the airflow and forces.

The biggest risk of virtualization is a loss of valuable feedback and interactivity. By removing the turbine, as described above, learners would not be able to feel actual forces resulting from wind attacking the wing. Hence, one should be aware of the advantages and disadvantages of those different types of AR exhibits and consider virtualization thoroughly case by case. The spectrum described above is depicted in Figure 1.

AR adds a whole new range to the spectrum of science museum exhibits. Starting from Hybrid AR Exhibits to Exclusive AR Exhibits, physical complexity is removed with increasing virtual complexity. Hereby, Hybrid AR Exhibits add new possibilities to interact with science exhibits, while Exclusive AR Exhibits also increase flexibility especially regarding learning content, reproducibility, and mobility. Thus, Exclusive AR Exhibits provide the basis for fully functional miniaturized exhibits which can be taken away.

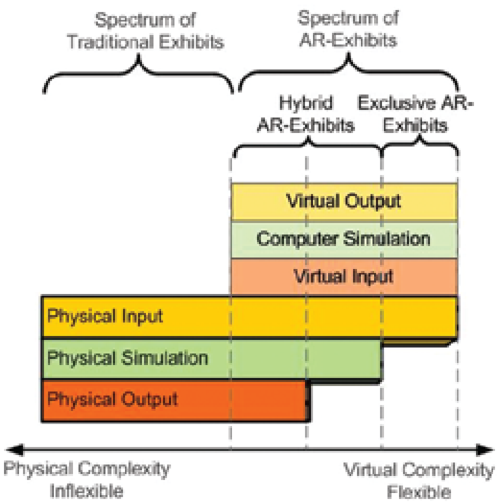


Figure 1. *The spectrum of AR Exhibits*

Finally one should keep in mind the fundamental qualities of a Science Center To Go exhibit which we determined in a previous paper [3]:

- Mobility: Miniaturizing exhibits by shifting simulation functionality into Mixed Reality
- Tangibility: Preserve the users' hands on experience
- Mass Producability: Increased virtuality enable simplified physical components to lower the barrier for mass production
- Accessibility: Miniaturized to pocket size; using common devices that are common in everyday life, such as regular PCs or smart-phones,
- Modularity: Follow the principle of modularity for extendable comprehensive exhibits and to provide a shareable collaboration platform.

4. A science centre in a suitcase

The Science Center To Go software is based on the MORGAN AR/VR Framework and runs on typical desktop PCs and mobile computers [14]. For tracking purposes we made use of the marker based ARToolkitPlus computer vision library [15], a further development of the original ARToolkit[16].

The process chain of creating a miniature exhibit is visualized in Figure 2.

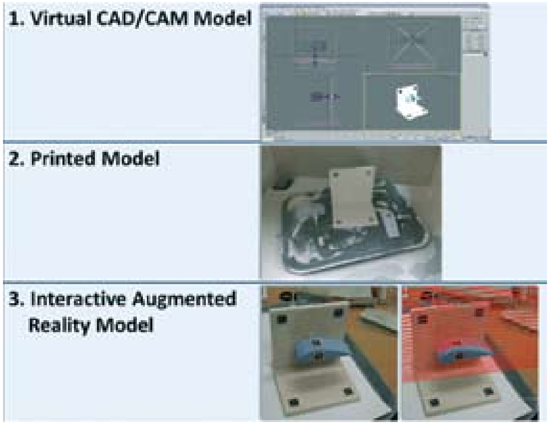


Figure 2. *Three steps to a Science Center To Go exhibit*

First a virtual base model of the exhibit is designed. In the next step a sufficiently accurate physical representation of this CAD model is being created. We use a Spectrum Z™510 3D printer providing us with an accuracy of a tenth of a millimetre. All further virtual information is then added in reference to the virtual base model. Fiducial markers serve as tracking points to precisely register the physical representation model and superimpose the physical miniature exhibit with virtual content.

After the MiniWing miniature proofed to be valuable, we now create new exhibits to comprehensively test and improve the Science Center To Go approach. The design of new exhibits follows the basic requirements of mobility, tangibility, mass producability, accessibility, and modularity, as it is detailed in [3]. Moreover, they are created in close cooperation with teachers and educational scientists to better meet the school curriculum. A typical setup of the current version of the Science Center To Go is shown below in Figure 3.

Figure 3. *Typical Science Center To Go setup: from right to left a suit case holding all exhibit parts, a laptop, and the playground for experimenting*

The suitcase stores all necessary elements for the existing five exhibits. Also included in the suitcase is a laptop with a touch screen, a webcam and a little stand. The webcam is placed on the stand and connected to the computer. On startup the computer directly opens the main screen where each experiment is represented by an image. Each image displays the corresponding experiment in action, also serving as guidance for users to correctly setup and use the system. After setting up the desired exhibit in front of the webcam a simple touch on the according image starts the software. The webcam stream is displayed on the computer screen and augmented with additional content. In the following we will describe the five exhibits currently included in the suitcase.

4.1 The Mini Wing Experiment

The MiniWing consists of a small box that stores the model of an airplane wing. The wing is about 5.5cm long, 3cm wide and 1.5cm high. It is connected to an axle that fits into a hole of the box (as seen in Figure 4). After the wing is brought into position, the user can easily rotate it and try out all possible angles of attack.

Only two markers are necessary for the Mini Wing: one is attached at the top of the box while the other one is placed directly on the wing. When the user rotates the wing, the software determines the current angle of the wing by analyzing the tracking values of both markers.

The virtual representation shows the way the air flows around the wing according the angle of attack. Animated arrows visualize the different speeds of air, lift, and drag of the wing.

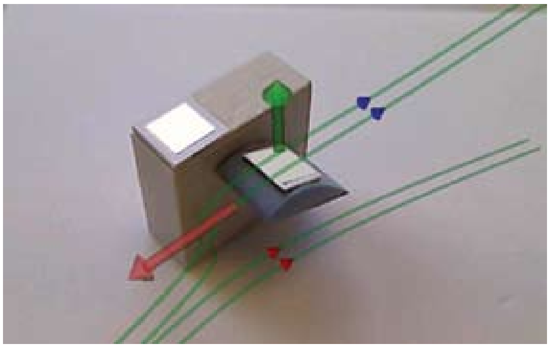


Figure 4. *the Mini Wing exhibit augmented through the airflow. Two arrows are displaying the lift and drag*

This way the user is able to learn firsthand about the Bernoulli Effect. By experimenting and interpreting the results, they learn that the best angle of this wing for optimal lift of the plane lies between 15 to 20 degrees.

In further iterations differently shaped wings will be added. Also a fan will be integrated to control the air stream.

4.2 The Doppler Experiment

The Doppler Experiment consists of a fire truck and a virtual microphone representing a sound recording device or listener. The fire truck is stored in the same box with the wing. The user should open the box and put its lid in front of the camera - a virtual microphone appears at the marker of the lid.

The fire truck also holds a marker on its roof top. As soon as the truck is visible to the camera, sound waves are displayed and the sound of a fire truck siren goes off. The sound propagation is animated in a sequence of wave fronts that start off from the trucks siren and expand concentrically away from the truck. The waves are emitted in a constant frequency. When the user moves the truck he moves the source of the sound waves causing the wave fronts to be shifted closer together in the direction the car is moving; the wave fronts are shifted further apart in opposite direction (compare Figure 5). At the same time the pitch of the siren audio is increased when the truck is moved towards the microphone and decreased when the truck is moved away. The pitch of the siren also changes when the user moves the microphone.

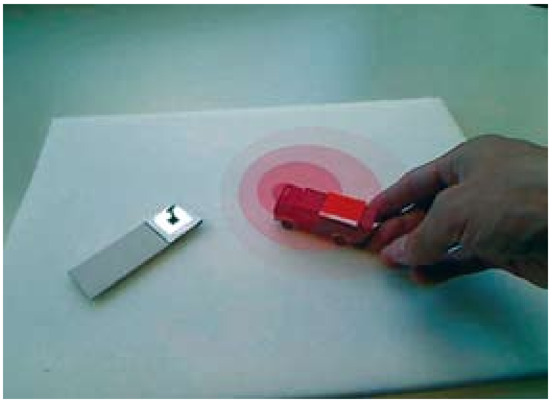


Figure 5. *Sound waves of a fire truck displayed at the Doppler exhibit.*

By moving fire truck or microphone the user gets an audio-visual feedback representing sound waves. This way users get a chance to learn about the Doppler Effect and the importance of relative difference in velocity between listener and the source. Observations made at this exhibit might easily be transferred to other physical phenomena related to the propagation of waves.

In further iterations different vehicles will be added providing a variety of sounds. Scenarios will be worked out to learn about the sonic barrier and frequency shift of moving light sources.

4.3 The Double Slit Experiment

The initial version of the double slit exhibit consists of the Mini Wing's box, a floor board and a screen with either a single or a double slit (see Figure 6). The box serves as the end projection plane. The selected slit screen should be fixated on the floor board so that it faces the projection plane on the box.

The slit screens and the box are registered via markers. The floor plane works as a fixation to ensure proper alignment and the right distances among all pieces.

Users are invited to test this setup with a virtual particle cannon or a wave field. In particle mode a virtual cannon appears at one end and starts firing virtual little "cannon balls" at the slit screen. Some of the balls are deflected while some pass the slit. The box projection plane is not deflective. When a ball passes through a slit towards the box it sticks to the box as soon as it hits it. After numerous balls a pattern analogous to the slit screen appears at the projection plane.

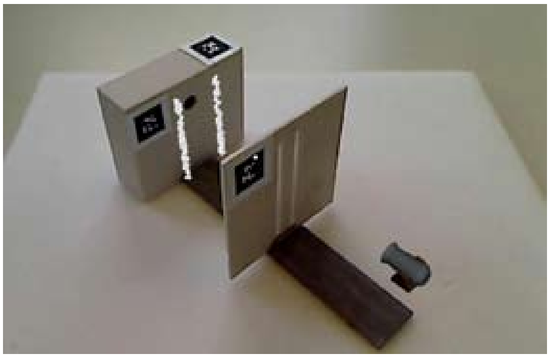


Figure 6. *The double slit setup consisting of a floor board (dark), the slit board in the foreground, a box as a projection plane, and a virtual cannon*

Users might be surprised when they test the same setup with waves. In this mode the cannon is replaced by a source sequentially emitting waves with a certain frequency. Wave fronts are spreading concentrically from the source. When a wave front hits a slit on one side a new concentric wave front goes off on the other side of the slit. The projection plane at the box finally shows the resulting interference pattern. For a single slit this results into a bright band in the middle of the box. Is the single slit replaced by a double slit the projection turns into several bright bands of light as shown in Figure 7.

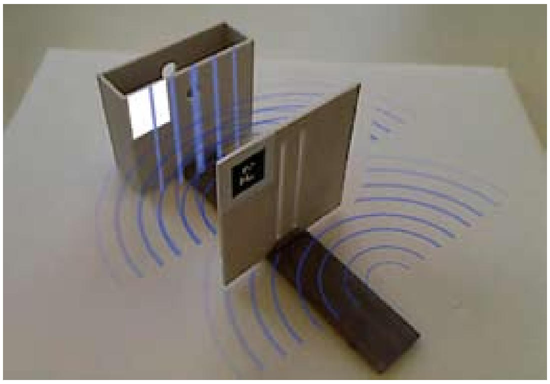


Figure 7. *The double slit experiment show¬casing a wave field.*

The waves are visualized and animated allowing ambitioned observers to search for areas of constructive and destructive interference.

By experimenting with the double slit exhibit users learn about wave propagation, interference, the particle wave duality of light, and quantum particles opposed to normal particles.

The current version is an initial prototype which obviously lacks some fundamental interactivity. In its next iteration learners will have more possibilities to change important parameters. They will be able to change the double slit distances, the distance between the slit screen and the projection plane, as well as the frequency of the wave emitting source.

4.4 The Double Cone Experiment

The double cone miniature consists of two rails of 12cm length each. The rails are jointly connected on one side; on the other side each rail rests on a ramp. The ramps provide an inclination of 1.5cm by 3cm. Additionally four rolling objects are available to be put on the rails. Three of the rollers are double cones and one is a cylinder. The opening angle measured alongside the double cones differs between 15, 30 and 45 degrees.

As shown in Figure 8 the rails are resting on ramps on one side. If the cylinder is put on the construction it will role down the slope. However, when a double cone is set on the rails it might as well role the opposite way, up the hill.

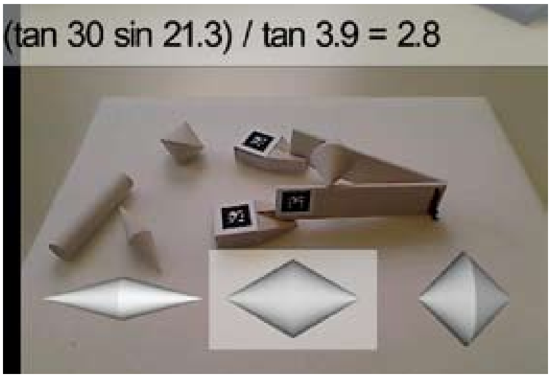


Figure 8. *The double cone exhibit consisting of two rails, two ramps and four roller objects. The double cone selection interface buttons are shown in the bottom the resulting formula is displayed at the top of the screen*

Three angles are important to understand and predict the behaviour of the double cones. One is the opening angle of the double cone roller (α), the other is the opening angle of the rails (β), and the third one is their inclination (χ). The angle referring to the double cones shape is selected via the user interface. Three markers are used to precisely capture the remaining angles. The opening angle is calculated from the two markers on the ramps and the resulting distance between both ends of the rails. The slope could have been determined directly from the orientation of the marker attached to the rail. Though, for increased precision the marker on the adjacent ramp is used to determine the position of the rail alongside on the ramp which gives us the lift of the rails ends. From here we are able to precisely deduce the inclination.

The relation of all three relevant angles may be described by the following expression:

$$\frac{\tan\alpha * \sin(\frac{\beta}{2})}{\tan\chi} \qquad \text{(I)}$$

If the result of this expression is greater than 1 the selected double cone should role towards the ramps otherwise it roles in opposite direction. The setup allows learners to easily change all relevant angles. The opening angle of the ramps is changed by moving the ramps apart. The incline is changed by pushing the rails up or pulling them down the ramps. The roller object has to be selected using the on screen buttons for each double cone. The formula for predicting the behaviour of the experiment is shown and instantly updated at the top area of the AR-screen.

This exhibit directly estimates the prediction model described by a mathematical expression and a real experiment. Hereby learners should be able to learn about the physical logic underlying the double cone experiment. Those experiments might also reveal typical misconceptions related to gravity.

In a next iteration it is planned to highlight the relevant angles on the camera image.

4.5 The Boltzmann Experiment

The Boltzmann experiment contains three objects: A refrigerator, a heating surface, and a thermometer. Since touch is important for hands on learning the refrigerator actually gets cold and the heating surface heats up. The exhibit also includes a functioning infrared thermometer, which displays the real temperatures of all objects.

Each object is registered through a marker. The markers of the fridge and the heating surface are used to determine the areas of high and low energy. The energy level between those two extremes is smoothly interpolated to provide a realistic transition.

After setting up the experiment users are able measure the temperature with the thermometer at different areas of their setup. Additionally, molecule movement is visualized at the top of the thermometer (see Figure 9). On the AR screen users might observe that molecules in areas of a high energy, near the heating surface, move faster than molecules around areas of low energy, e.g. inside the refrigerator.

With this experiment learners should get a deeper understanding and insight into the relation between energy, temperature and molecule movement. In a next version a graph will be added showing the Boltzmann distribution.

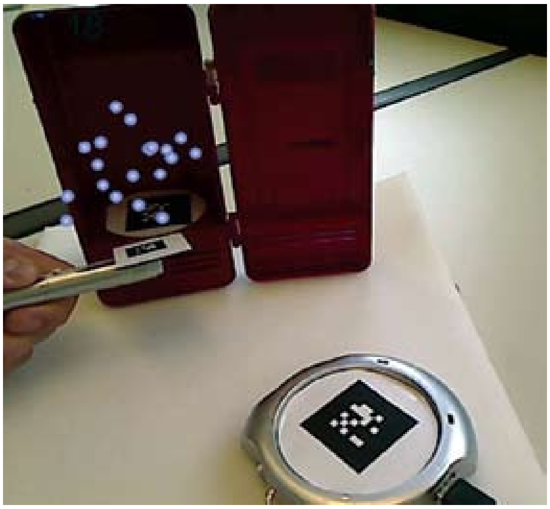


Figure 9. *The Boltzmann exhibit: Heating plate in the front refrigerator in the back. The user holds the thermometer into an area of low energy and recognizes a slower movement of the molecules.*

5. Evaluation, Discussion and Future Work

The five exhibits described above where consecutively developed. While the Mini Wing went already through 3 iterations newer exhibits are in their initial generation. The Mini Wing and the Doppler have been tested most extensively. Results of these tests and related evaluations are described in [17].

The Mini Wing has also been presented at multiple venues. The feedback in general was quite positive while critical feedback usually was constructive. One child testing the Mini Wing, for example, asked why it would not feel any wind blowing at the wing when it could see an air stream on the computer screen. So we bought a USB powered fan to be prepared for this question next time. After testing the fan we found that the actual air stream created a much richer experience. We underestimated the sense of touch, and did not add a real air stream although we were trying to develop science centre like exhibits. The critical comment of the child made us reconsider the Mini Wing in respect to the spectrum of AR-exhibits as described in section 3.

For the development of miniature exhibits we deduced that one should first determine all senses activated by the real experience. As soon as a sense is not addressed due to virtualization, there is a good chance that certain expectations are not met and the whole experience does not “feel right” for the learner. Realism might be important for the learning effect, since the output created by the AR-component should be believable in order to be believed. The following interesting questions arise from this observation: Do realistic miniatures achieve better learning effects than others? Does, for example, a real air stream improve learning because it makes the virtual AR information more believable? Taking this further leads to a more fundamental question in learning in general: Do we learn better on abstract or concrete content? These questions seem to be relevant for any future work and need to be addressed.

Other feedback we received by an expert was concerning the size of the exhibit. Does a miniature exhibit achieve the same learning effect as its big replication? It is important to extract characteristics that change when an exhibits is being miniaturized and to find out how they influence the learning experience. Some of the miniature exhibits portrayed above are already available in different sizes. The Mini Wing for example is a scaled down copy of an exhibit created for the first project CONNECT; the original wing is ten times as big as the miniature wing. Just as well the double slit is available in a version which is approximately three times bigger than the one in the suitcase.

The exhibits will also be systematically evaluated and refined. There is still plenty of room for improvements in all relevant areas. First of all, concrete guidelines on the design of miniatures are inevitable. Some general answers and guidelines are still missing, such as when should the virtual content exactly match reality and when should it be metaphorically modified. Obviously, we also need to develop and test further exhibits to cover a wider range of topics. Before we create new exhibits, we first will have to improve modularity of the existing pieces.

Since the miniatures serve as Tangible User Interfaces for the AR system there also needs to be done some more testing on human computer interaction especially with miniature exhibits. In respect to this the whole AR component might be revised and updated where necessary.

Technically it might be helpful to integrate an alternative computer vision tracking based on natural features. The cause why natural feature tracking has not yet been integrated has two main reasons: first it demands more computing power, and second it is hard to place many features on small surfaces, as it would be necessary for miniature exhibits. Natural feature tracking, however, could probably be integrated after a proper redesign of the exhibits. The other alternative is edge based object tracking. This variant seems to be even more promising, since we already have accurate real representations of our virtual models. Both tracking approaches need to be kept in mind for further updates of the AR component.

Since mobility is a key factor for Science Center To Go exhibits, we should also follow recent trends and move the system to mobile handheld devices. Currently we focus on common tablet computers or laptops as end user devices. A shift to mobile devices and smart phones would also increase accessibility and broaden the audience.

Finally and most importantly the miniature exhibits have to be evaluated thoroughly to analyse the learning effect. With its major target group of pupils at schools it has to be integrated into the school curriculum. Both aspects will be approached in the coming evaluation phases of the SCeTGo project.

We are still confident that the Science Center To Go idea is a valid approach with very high potential for success. With further work and research similar miniature exhibits might soon find their way into every day learning.

6. Acknowledgement

We thank our colleagues at the Collaborative Virtual and Augmented Environments Department at Fraunhofer FIT for their comments and contributions. We further wish to thank our project partners of the CONNECT, EXPLOAR, and SCeTGo projects for their ideas, cooperation, and support. CONNECT was partially funded by the European Commission (FP6-2002-IST-1-507844). EXPLOAR and SCeTGo were and are both co-financed by the European Commission within the framework of the Life Long Learning Programme.

7. References

[1] Sotiriou, S., Anastopoulou, S., Rosenfeld, S., Aharoni, O., Hofstein, A., Bogner, F., Sturm, H., Hoeksema, K.: Visualizing the Invisible: The CONNECT Approach for Teaching Science. ICALT 2006: 1084-10

[2] Wittkämper, M., Braun, A-K., Herbst, I., Herling, J.: A Distributed System for Augmented Reality Experiences in Science Centres and Museums; Technologies for E-Learning and Digital Entertainment (2007), pp. 936-946.

[3] Buchholz & Wetzel (2009). Introducing cience Centre TOGO - A Mixed Reality Learning Environment for Everyone's Pocket; IADIS International Conference Mobile Learning 2009 (pp. 104-110), Barcelona, Spain 2009

[4] Ishii, H. and Ullmer, B.:Tangible bits: towards seamless interfaces between people, bits and atoms, Proceedings of CHI '97; Conference on Human Factors in Computing Systems, pages 234-241.

[5] Ullmer, B., and Ishi, H.: Emerging Frameworks for Tangible User Interfaces; in "Human-Computer Interaction in the New Millenium," John M. Carroll, ed.; © Addison-Wesley, August 2001, pp. 579-601.

[6] Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., and Silverman, B.: Digital Manipulatives: New Toys to Think With; Proceedings of CHI'98 Conference, Los Angeles 1998

[7] Kosmos.de, "experimental kits a-z" [visited 22-Jul-2008]

[8] Lego.com MINDSTORMS NXT Home, mindstorms.lego.com [visited 22-07-2008]

[9] Bagnall, B., 2007. Maximum LEGO® NXT: Building Robots with Java Brains, Variant Press. Available from: <http:// www. variantpress.com> [visited 11-Nov-2008]

[10] ARiSE, 2009, ARiSE – Augmented Reality in School Environments Available from: <http://www.arise-project.org/> [visited 08 -Jan-2009]

[11] Medina, E., Chen, Y. & Weghorst, S., 2007. Understanding biochemistry with Augmented Reality, Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007, Chesapeake, VA, USA, pp. 4235-4239.

[12] Bier, E., et al., Toolglass and Magic Lenses: The See-Through Interface, Proc. ACM Conf. Computer Graphics and Interactive Techniques (Proc. Siggraph), ACM Press, 1993, pp. 73–80.

[13] ARTag, http://www.artag.net/ [visited 30-Sept-2010]

[14] Broll, W., Lindt, I., Ohlenburg, J., Herbst, I., Wittkämper, M., and Novotny, T.: An Infrastructure for Realizing Custom-Tailored Augmented Reality User Interfaces, IEEE Transactions on Visualization and Computer Graphics, 11 (6), Nov. 2005, 722-733.

[15] Wagner, D. and Schmalstieg, D.: ARToolKitPlus for Pose Tracking on Mobile Devices. Proceedings of 12th Computer Vision Winter Workshop (CVWW'07), February 2007

[16] Kato, H. and Billinghurst, M. 1999. Marker Tracking and HMD Calibration for a Video-Based Augmented Reality Conferencing System. In Proceedings of the 2nd IEEE and ACM international Workshop on Augmented Reality (October 20 - 21, 1999). IWAR. IEEE Computer Society, Washington, DC, 8

[17] Salmi, H., Sotiriou, S., and Bogner, F. 2009. Visualising the Invisible in Science Centres and Science Museums: Augmented Reality (AR) Technology Application and Science Teaching, pp. 185-208. In Karacapilidis, N. (ed.): Web-Based Learning Solutions for Communities of Practice. Developing virtual environments for social and pedagogical advancement. Information Science Reference. Hershey, New York. ISBN 978-1-60566-711-

Associating Sports Activities with Scientific Enquiry and Experimentation

Angelos Lazoudis
Ellinogermaniki Agogi
Dim.Panagea Str., 15351 Pallini, Greece
angelos@ea.gr

Abstract

The incorporation of ICTs in education & training systems is becoming more & more important, allowing us to develop new approaches to learning, life and work. Furthermore, despite the increasing use of ICTs, it is strongly believed that our educational system has to shift from the traditional paradigm of teacher-directed learning to learner-centered curricula that promote the development of lifelong learners who can think critically, solve problems, be creative & collaborate at work.

The Kicking Life into Classroom (KLiC) project by taking into account these aspects proposes an inquiry-based approach of science teaching pedagogy that bridges the gap between formal & informal education and brings science & scientific objects closer to the learners by using wearable intelligent sensors that associate every day and sports activities with scientific inquiry and experimentation.

Keywords

Accelerometers, Sports performance, Teaching Science, Wearable computers.

1. Introduction

Over the last decade the development of new technologies and their implementation in sport activities has enhanced our knowledge about the physics of sports and that of human movement as well as athletes' techniques adopted for increasing their sport performance. Such technologies include among others, computer systems (with hardware and software components) that are capable of capturing images or recording videos that can be further used for performing dynamical studies [1], analysing human motion [2-3], investigating basic principles of classical mechanics [4], reconstructing 3D ball trajectories in basketball [5] or understanding the physics of various phenomena [6]. Furthermore, new powerful processors allow the creation of complicated simulations in sports [7] while the application of small and accurate accelerometers can be used for measuring running speed during exercise [8] or for performing simple physics experiments [9]. Within this framework we present the KLiC system (and its educational approach) that enables, through the use of embedded sensors [9] during various experiments or sport activities, the collection of physical and scientific data. This data is transmitted and presented to the students in real time, demonstrating the basic laws of the physical phenomena taking place.

2. The KLiC approach

The KLiC system introduces innovation both in pedagogy and technology. It proposes the introduction of innovative tools in science education, that allow for as many links of science teaching as possible with everyday life. Sometimes students lose interest in science because they cannot relate what they are being taught to their everyday lives. The introduction of the KLiC system aims at overcoming the barriers imposed by the traditional classroom setting by introducing to science teaching an innovative combination of a new approach to learning with application of new technologies. The technology used allows for high school students to use their everyday life as the field where they conduct sophisticated experiments and thus deepen their understanding of the science concepts involved in the activities.

The KLiC approach represents an integrated effort to reconnect science teaching in secondary school with real life of students. Within the framework of the KLiC project wearable computers and intelligent sensors are used by students for experimentation, data collection and storage.

The recorded data can then be utilized by a specially designed User Interface to graph trends and patterns and investigate the laws of engineering and physics. Students have the opportunity to collect data from a variety of sensors, compare measurements and design new experimental activities on their own. In this way, teaching makes as many links as possible between the natural sciences and daily life, and research becomes more of a collective process. KLiC system revealed to students hints of the magic aspects of physics and natural sciences while at the same time extended the capabilities of the school science laboratory much beyond its conventional borders.

In order to obtain the maximum of flexibility, lesson plans are designed to support the system's introduction in the schools and the learning process. This is facilitated by the system's modular approach: Small devices, so called axions (accelerometers), collect data during students' experimental activities. In combination with transmission devices a workstation equipped with specially designed software for measurement and analysis of the collected data should enable the students to easily quantify these observations, identify schemes or patterns and derive hypotheses and theories. The combination of these devices builds the integrated KLiC system.

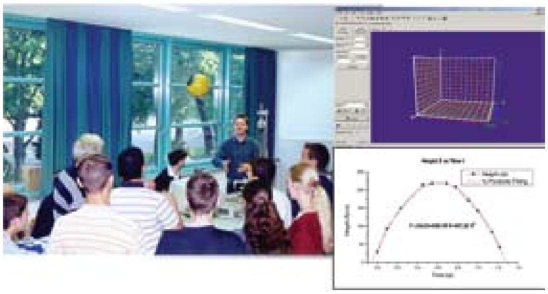


Figure 1: *The KLiC project demonstrates ways for the re-engineering of the high school science laboratory into a thought-provoking, engaging and challenging environment through the use of embedded sensors.*

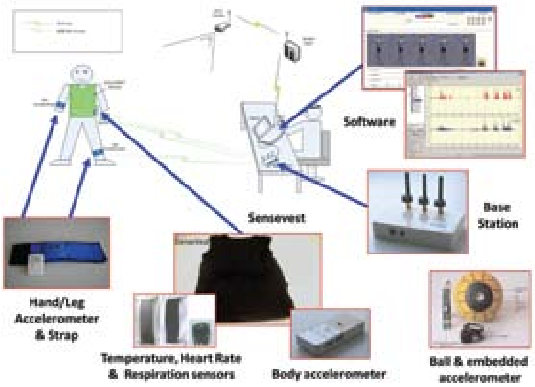


Figure 2. *General architecture of the KLiC system and its sensors.*

3. The KLiC system

The KLiC system consists of the following software and hardware modules:

- The Monitoring Station that is a laptop or desktop PC with the system monitoring software.
- The radionetwork Base Station, which connects wirelessly the monitoring station with the peripheral sensor units born by the students/athletes or the ball(s).
- The SenseVest, that is a shirt without sleeves worn by the student/athlete, which incorporates three (3) embedded sensors for measurement of heart rate, respiration rate and external body temperature. An additional body acceleration sensor device (BoS) is contained into a special small pocket at the lower front of the SenseVest.
- The Body Sensor device (BoS), that includes a 3-dimensional acceleration sensor for the movement of the student/athlete body and in conjunction with the embedded sensors in the SenseVest transmits to the Monitoring Station all student/athlete physiological data as well as his/her body acceleration values.
- The Arm/Leg Accelerometer (ALA), that is a 3-dimensional acceleration sensor worn on the wrist or the ankle of the monitored student/athlete with the aid of specially made straps, which provides for hand/leg acceleration values during the physical activity within a dynamic range of +/- 12g (g = nominal gravity acceleration equal to 9.8 m/sec^2).
- The KLiC straps, that are dedicated straps for holding the ALA devices on the wrist or the ankle of the student/athlete. The straps consist of a special fabric fastened with Velcro bands with a waterproof pocket on the upper part. They are available in two sizes, one small and one large.
- The Ball Accelerometer (BA), that is a 3-dimensional ball acceleration sensor, contained along with a pair of Li-Ion batteries inside a specially made plastic tube and the whole assembly fitted into a common FILA standard polo ball via a suitably cut and waterproof glued rubber tube surrounding the assembly.

The general architecture of the system and its sensors is illustrated in the Figure 2 while a full description of the system is provided in the On-line manual available at www.klic-project.eu.

4. The KLiC educational content

The learning scenarios (demonstrators) that support the application of the system in formal and informal education settings consist of Teacher Notes and Student Worksheets.

Teacher Notes are meant for teachers and should give good background how to prepare lessons with students. In an inquiry-based approach there is great room for teachers to adapt, innovate, to work in their own way with students but there are some important principles that should be followed and teachers should be aware of them. This is a reason that the topic ‘Inquiry-based character’ is part of the template.

Student Worksheets are meant for use as classroom materials for students. How extended these materials are depends on the activity goal, inquiry-based level and student level.

The procedure for designing educational scenarios is supported by a ‘Short guide for designing inquiry-based teaching materials’. In this guide is given some background about science inquiry approaches, types of inquiry activities and exemplary inquiry skills. The aforementioned guide along with educational scenarios developed by the consortium is presented in detail at www.klic-project.eu.

The first two-pages of the 'Short guide for designing inquiry-based teaching materials' document are depicted in Figure 3.

#	Title of the Demonstrator	Educational Environment
1	Introduction to fencing	Sport Club - Informal
2	Introduction to Table Tennis	Sport Club -Informal
3	Parachute Jump	School, University - Formal
4	Ski Jump	School - Formal
5	Testing materials used to maximise skier's performance	School - Formal
6	Gymnastic-Trampoline	University - Formal
7	Angular amplitude of a swing's oscillation	School - Formal
8	Half-life period of a damped oscillation	School, University - Formal
9	Study of elastic oscillations	School - Formal
10	From the study of elastic oscillations in the physics laboratory, to bungee jumping II	School - Formal
11	Studying circular motion	School - Formal
12	Pirouettes, pirouettes	School - Formal
13	Treadmill running speed vs. strength	School - Formal
14	Cycling on a flat road, cycling up hill	School - Formal
15	Influence of respiratory rate on the effectiveness of exercise	School - Formal
16	Hydrostatics	School - Formal
17	Circular Motion	School - Formal
18	Oscillating Motion	School, University - Formal
19	Motion on an inclined plane	School - Formal
20	Oscillation and waves	School - Formal
21	Motion and rest	School - Formal
22	Elastic Pendulum	School, University - Formal
23	The gravitational pendulum	School - Formal

Figure 3. *Short guide for designing inquiry-based teaching materials.*

All the above scenarios are available in pdf format at KLiC (www.klic-project.eu) project's website in the section "Scenarios" as shown below. This series of exemplary scenarios illustrates the usage capabilities of the KLiC system and also indicates to the learner ways of designing new experimental activities.

Figure 4. *The KLiC website hosts a set of demonstrators (learning scenarios) in the Scenario section (red circled area).*

5. Objectives

The aim of the KLiC project is to demonstrate ways for the re-engineering of the high school science laboratory into an engaging, thought-provoking, and challenging environment, a pathway to the real scientific world. Through the use of embedded sensors, data collected during a series of experiments were transmitted and presented to the students in real time, demonstrating the basic laws of the physical phenomena taking place.

More precisely, the KLiC project aspires to:

a) **Teach science through the use of advanced technological applications**

The new technology offers to the learners a unique possibility to use high-end technological products in their every day life. The project is ideally suited to help young people and adults to learn to use the Internet and computers in a scientific environment and is designed to promote independent and creative activity.

b) **Transform the classroom to an experimental laboratory for all.**

The learners perform experiments with their own data. In this way their activities are transformed to scientific experiments and their classroom or sports ground is transformed into a scientific laboratory. Such activities are viewed by the young & adult learners as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression.

c) **Reinforce interdisciplinary approaches in the process of learning.**

The project focuses on interdisciplinary education. This approach supports that educational experiences should be authentic and encourage students to become active learners, discover and construct knowledge. Authentic educational experiences are those that reflect real life, which is multifaceted rather than divided into neat subject-matter packages. The educational context of the KLiC project is not transmitted in a theoretical way but rather in an experimental way in the form of a real life experience.

6. Implementation & Trials

The piloting of the application at the first level will be done in repeated cycles of user-extended trials. Each cycle includes the design, the development, the trials and the evaluation, which is the input for the next cycle in the user-centred product's development approach. The project team intents to refine and finally define a feasible application that will be tested and validated locally, with the aim of being replicated in the future in different environments world-wide and allowing overall networking.

The implementation and validation activities within the framework of the KLiC project will begin in the fall of 2010 and are expected to run until the end of 2011 and will be performed at

a) Schools in Greece, Austria, Romania (and in a few more European countries through the development of the KLiC User Group)

b) Universities in Sweden, Greece, The Netherlands and UK

c) Sports clubs in Sweden, Austria and UK.

The collected and validated data from all planned activities will be published by the completion of KLiC (December 2011).

7. References

[1] Eriksen H. K, Kristiansen J. R, Langangen Ø, Wehus I. K, How fast could Usain Bolt have run? A dynamical study, Am. J. Phys.77 (3) p. 224-228; March 2009.

[2] Heck A, van Dongen C, Gait analysis by high school students, Phys. Educ. 43 (3) p. 284-290; 2008.

[3] Ellermeijer T, Heck A, Walk like a physicist: an example of authentic education. Physics in New Fields: Proceedings of GIREP Conference (Lund, July 2002) http://pinf.fysik.lu.se/abstracts/fullText/148.pdf

[4] Wehrbein W. M, Using video analysis to investigate intermediate concepts in classical mechanics, Am. J. Phys. 69 (7) p 818-820; July 2001.

[5] Chen H-T, Tien M-C, Chen Y-W, Tsai W-J, Lee S-Y, Physics-based ball tracking and 3D trajectory reconstruction with applications to shooting location estimation in basketball video, J. Vis. Commun. Image R. 20 (2009) p. 204–216

[6] Heck A, Uylings P, Kedzierska E, Understanding the physics of bungee jumping, Phys. Educ. 45 (1) p. 63-72; 2010.

[7] James D., The physics of winning - engineering the world of sport, Phys. Educ. 43 (5) p. 500-505; 2008.

[8] Guinhouya C. B, Hubert H, Dupont G, and Durocher A, Relationship between the MTI accelerometer and (actigraph) counts and running speed during continuous and intermittent exercise, Journal of Sports Science and Medicine (2005) 4, p. 534-542

[9] Knight J. F, Bristow H. W, Anastopoulou S, Baber C, Schwirtz A, Arvanitis T. N, Uses of accelerometer data collected from a wearable system, Pers. Ubiquit. Comput. (2007) 11: 117–132.

www.learningwithatlas.eu

Learning with ATLAS@CERN

ISBN 978-960-473-219-7