Specific targeted research project
IST call 4
FP6-2004-IST-4

Interactive Artifacts for Experiential Learning - a radical approach

RADICAL

Date of preparation: [Preparation date]

Participant no.	**Participant name**	**Participant org. short name**
1 (coordinator)		
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4		

etc. *(Check this participant numbering is reflected in the form A2 of each participant!)*

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RADICAL

Strategic objectives addressed

(If more than one objective , indicate their order of importance to the project. The main (first) Strategic objective must be one included in this call)

Proposal abstract

(copied from Part A, if not in English, include an English translation)

[Proposal abstract]

B.1 Scientific and technological objectives of the project and state of the art

Recommended length – three pages

(Describe in detail the proposed project's S&T objectives. The objectives should be those achievable within the project, not through subsequent development, and should be stated in a measurable and verifiable form. The progress of the project work will be measured against these goals in later reviews and assessments. Describe the state-of-the-art in the area concerned and how the proposed project will enhance the state-of-the-art in that area.)

Computer support for education traditionally starts with a data model based on an abstract mathematical representation of the objective world of a phenomenon to be studied. It then proceeds to design a program to demonstrate some aspects of the phenomenon in the learner's subjective world. This promotes the idea of the computer as an efficient means of instruction and information delivery, in keeping with the concept of 'learning objects'. An example of such a program might be a virtual laboratory based on a mathematical model of electromagnetic theory.

In this project, our primary emphasis is on starting from the learner's living environment, as experienced through his/her observations, and using the computer to support the journey towards a scientific understanding of an observed phenomenon. Our aim is to enable the learner to construct an interactive artefact (IA), step by step, as he/she traces a path to comprehension through the Zone of Proximal Development (ZPD). The emphasis is on reconciling *what is observed* with *what is believed* through creative construction, taking alternative viewpoints and possibly even thought-provoking and time-consuming exploration. The kind of artefacts we have in mind are such as an experimental scientist like Faraday constructed in the process of discovering and first trying to understand electromagnetic phenomena.

Our project will demonstrate and critically evaluate a new methodology for developing interactive artefacts for experiential learning. For this purpose, we shall apply a paradigm for computer-based modelling radically different from conventional computer programming, called *Empirical Modelling* (EM) []. The key idea in EM is the incremental construction of artefacts that embody the patterns of observables, dependencies, and agency that we encounter in the phenomena we study. The notion of dependency invoked here is similar to that to be found in a spreadsheet, where updating one cell updates many *as if in one operation*. EM can be interpreted as 'a methodology for modelling with dependency'. Like the so-called 'scientific method', it guides the experimental scientist's model-building practice, but is in no sense guaranteed to generate a theory.

EM principles and tools have been developed and extensively used in Computer Science at the University of Warwick [by one of the consortium partners] [Beynon, Warwick CS] over many years. Prototype applications of EM to educational technology have also already been developed. Many examples can be found in the repository of models at [], and these will be the basis for a workshop at the ICALT'05 Summer School and an exhibit at the EU FP6 (?) Kaleidoscope Showcase events to take place in June and July. The scope of potential application of EM to educational technology is wide, and extends to many varieties of interactive computer assisted learning. This project aims to establish an intimate link between EM and experiential learning, with specific reference to variants of constructionist learning. By demonstrating that the principles we have deployed so successfully with computer science students at Warwick can be transferred to Europeanclassrooms, we shall approach our goal of 'realising the applications of dependency in interactive computer-assised learning' (RADICAL).

For our task of applying, elaborating, critically appraising and evaluating the RADICAL methodology in the school context, we have brought together three leading European research groups with a common interest in exploiting IAs for experiential learning. The research of these three groups, into I-blocks [Lund, Southern Denmark University], microworld simulations of sporting events [Pratt, Warwick University CeNTRE], and a variety of Kids Club activities [Sutinen, Joensuu] will provide a practical testbed to support the technology transfer, and afford state-of-the-art expertise in respect of classroom deployment of AI techniques, new technologies, principles of iterative design and evaluation. By building on their expertise, we shall extend the scope of EM application to encompass learning activities for which we only have proof-of-concept at present. These include forms of learning that are collaborative, distributed, situated and engage with mixed reality environments.

Each group will lead a strand of educational research, targeted at 9-15 year old pupils of science and technology, by developing IAs and an associated infrastructure to address a different aspect of studying complex phenomena. In each strand, the qualities and limitations of the RADICAL methodology will be evaluated by a two stage process involving comparative studies and rich case studies that will be phased and interleaved with further development. Evaluation of these studies will be both quantitative and qualitative. We seek to obtain empirical evidence from these studies to confirm several qualities of the methodology that have been informally remarked in previous project work. For instance

- the incremental construction of models closely reflects the evolution of understanding, stage-by-stage, so that there are unprecedented opportunities for auditing and documenting the development of IAs in the learning process;
- direct interaction via a distributed model - generalising concurrent use of a multi-user spreadsheet - has promise as the primary form of communication in collaborative learning;
- our methodology has proved capable of restoring self-confidence and self-esteem to students demoralised by the demands of conventional programming. *[more about eval?]*

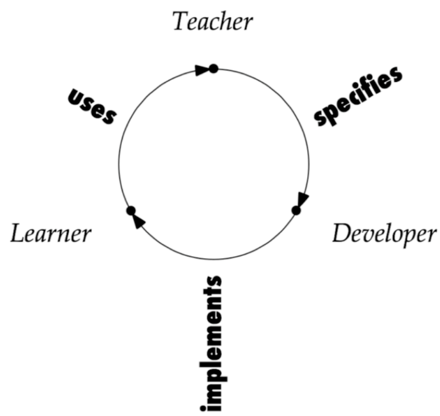
Our previous experience also indicates that EM has special merits in respect of the three key roles in constructionism: those of learning, teaching and building. With this in mind, the objectives of the educational strands will be aligned to these three roles. In I-Blocks, the primary emphasis will be on the *building* role, in the CeNTRE, on the *teaching* role, and in Kids Club, on the *learning* role. These roles will in turn be matched to three agendas in applying scientific principles as they relate to building [realising], explaining and understanding complex phenomena respectively. Typical questions that might relate to the learning activities in these three streams might then be: How to use IAs to support: to build an automatic vehicle that can negotiate an arbitrary system of roads and roundabouts? to explain the dynamics of interacting billiard balls? to understand [investigating] the human and technological factors that led to a railway accident? Existing IAs that help to address each of these questions will be further developed and adapted for classroom use in the course of the project. For instance, we might realise our existing virtual model of an automatic vehicle using the I-blocks technology, or add interfaces to our existing distributed model of a railway accident scenario so that it can be exercised in conjunction with operations in an actual model railway. In EM, extensions of models of this nature can be made by resuming the development process that led to their initial construction without any conceptual discontinuity.

We shall complement the practical investigations in the educational research strands by three orthogonal strands to enhance the principles and tools that support the RADICAL methodology. These will respectively address the application, implementation and evaluation of the methodology in its full generality. Drawing on expertise from cognitive science [Kommers, Twente] and qualitative and quantitative analysis of the results from the educational strands [Kutar, Salford], we seek to understand EM in its relation to learning theories, and to obtain more objective evidence (encompassing that gained from the specific studies within the educational strands) to support claims about its qualities and limitations in more general educational contexts (for instance, higher education, special needs, the humanities etc). A third strand of research, led by a research group experienced in implementing educational technology [Joy, Warwick CS], will address the demands of implementing new features (e.g. auditing capabilities, usb interfaces, internet distribution) to support the migration of the principal EM tool (the EDEN interpreter) to the educational environments, and establishing the infrastructure for wider dissemination. As our primary objective is to promote the widespread adoption of our methodology that is necessary to stimulate the further development it merits, we shall retain our existing policy of open source distribution of generic tools and resources. We believe that some of the more specialised products of the project may have commercial potential, however, and will be liaising with an educational software company [Pixton, Logotron] to explore these possibilities as they arise.

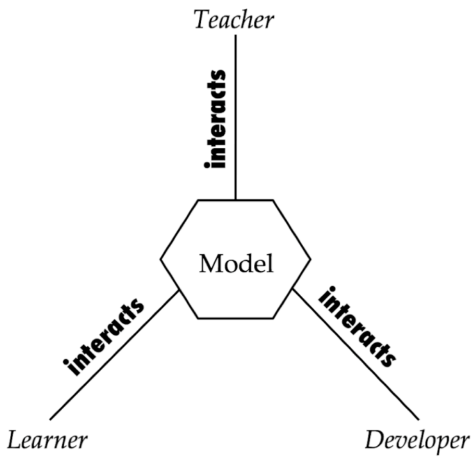
In support of these objectives, the key deliverables will include: output in the form of publications, reports and data analyses from rich case studies, papers on EM and learning, distributions of tools and repositories of models (both particular to the three educational strands, and relating to the core research on the RADICAL methodology), and a community of researchers and interested adopters in schools across Europe together with a supporting infrastructure.

State-of-the-art

The key issue addressed by adopting the RADICAL methodology is the integration of the roles of learner, teacher and builder that is implicit in the concept of constructionism.



Traditional constructivist framework



The RADICAL constructivist framework

Figure 1a depicts the conventional development cycle for artefacts to support constructionist learning. The learning, teaching and building activities correspond directly to using, specifying and implementing a program, and so take place in conceptually quite separate environments using totally different representations. For instance, from the builder's perspective, these activities use representations for userinterface design (e.g. statecharts), specification (e.g. UML diagrams), and programming (e.g. Java code), that are of no concern to the learner and teacher. Traditional attempts to overcome the problems of role integration in Figure 1b have to contend with the well-known hard problem of developing conventional programs so that they can be adapted to new requirements - a problem that is particularly acute in the learning context, where requirements change in response to cognitive demands is common, subtle and of the essence. In this respect, our approach is radically different from that of previous projects directed at similar educational goals, such as the WebLabs, WebKit and Playground projects, which work within a traditional programming framework. From a computer science perspective, the techniques employed in these projects (such as introducing tangible user interfaces, promoting cooperative development over the web, or animated programming ???) only complicate the real programming task, though they may make it superficially more attractive to children.

Our project addresses role integration by substituting EM principles for model-building for conventional programming. In the use of EM, as depicted in Figure 1b, builder, learner and teacher are all interacting with the same artefact in the same environment in conceptually the same way. It is no coincidence that - in an appropriate application of a spreadsheet in an educational context - the redefinition of a spreadsheet cell could signify an action on the part of the learner, the teacher or a builder. What links EM and the spreadsheet is 'modelling with dependency' - a fact to which we attribute the quality of spreadsheets as an educational technology cited by Baker and Sugden []. The additional ingredient introduced in EM is the RADICAL methodology - without this, the use of dependency may not deliver the cognitive advantages that underpin Figure 1b.

From an epistemological perspective, EM adopts a phenomenological stance that is oriented in the first instance towards 'expressive' rather than 'exploratory' models (cf. Doerr and Pratt []). This raises issues for validation (and related problems regarding assessment []) similar to those that arise in using spreadsheets as an expressive tool. This highlights the significance of the RADICAL methodology, which in effect constrains the modelling activity so that the patterns of observables, dependencies and agency in the model at all times faithfully reflect the patterns that are attributed to its referent.

B.2 Relevance to the objectives of the IST Priority

Recommended length – three pages
(Describe in detail the manner how the proposed project's objectives contribute to the scientific, technical, wider societal and policy objectives of the IST Priority as stated in this call.)

Learning and cognition

Objective 2a of the TEL workprogramme, to which the call for proposals relates, addresses "the link between learning and cognition, with the aim of increasing understanding of human cognitive and learning processes". A major strand in our proposal (see WP5) is concerned with how Empirical Modelling (EM) is linked to learning, and specifically what role the notion of dependency plays. Recall that dependency in this context is identified with the kind of simultaneous update that occurs in a spreadsheet - if we change one cell, others are observed to change as a result. A direct connection can be made with Dennett's observation [] to the effect that "the basic method of obtaining self-knowledge ... about our own internal states, tendencies, decisions, strengths and weaknesses" takes the form of: *Do something and "look" to see what "moves"*. Dennett goes on to remark that chimpanzees can use this capability to good effect to learn to retrieve food that they can only indirectly see and access. It is in this spirit that we shall evaluate dependency as a potential primitive ingredient of intelligence that can help us to better understand learning.

Within the project, both practical engineering and cognitive perspectives will be brought to bear on this issue.

The engineering perspective (cf. WP3)

In engineering terms, it has become apparent that it is difficult to build a complex adaptive system that can, for instance, simulate the learning activities of the chimpanzee, within the traditional artificial intelligence (AI) paradigm. In such AI systems (see e.g. [4],[5], [6]), the approach has been to create intelligent robotic systems which to a large degree split hardware and software development into two separate processes, and work with the software - that is to say the control problem - with a sense-model-plan-act architecture (see Fig. 1, Left). Though sophisticated methods may be applied to the control (e.g. neural network control [1], evolutionary robotics [2], machine learning [3]), the planning is taking place in the abstract, symbolic model that is derived through the sensing and modelling. This leads to the well-known symbol grounding problem, frame problem and brittleness problem where there is little correspondence between the symbol model and the real world, so that the performance in the real robotic artefact may deteriorate when compared with what is expected in the ëperfectí simulation model. From a more philosophical point of view, it can be said that traditional AI favours a brain-body duality, and views the brain to be the important, defining component of intelligence.

In contrast to the traditional concept of intelligence as abstract and rational, modern AI focuses on manifest qualities of flexibility, adaptivity, and embodiment, as exemplified in flexible robotic systems. Intelligence is then defined *as the ability to generate a variety of behaviours while complying with the givens of the system*. In an modern AI approach (e.g. [7]) to building interactive artefacts to serve as intelligent learning tools, the emphasis is on construction in the real, physical environment that utilises the characteristics of the real world in the development. The resulting control systems provide a close loop between environmental stimuli and actuation in the environment through the use of primitive behaviours executed in parallel and coordinated to provide the overall behaviour of the system. In this way, the overall behaviour of the system becomes the emergent effect of the interaction with the environment and the coordination of the primitive behaviours on the part of the learner-builder.

The fact that the modern AI approach demands embodiment in a real physical environment is both a virtue and a handicap. Ideally, we should like to be able to design modern AI systems without necessarily having to invest in potential expensive technologies, or to be obliged to work within the constraints that such embodiment imposes. It is in this respect that the possibility of using the concept of dependency to explore the integration of the virtual and actual has promise.

As a novel approach, we shall expand the more classical view on behaviour-based systems to include not only the coordination of primitive behaviours in terms of control units, but also include coordination of primitive behaviours in terms of physical control units. We can imagine a physical module being a primitive behaviour. In this way, the physical organisation of primitive behaviours - together with the interaction with the environment - will determine the overall behaviour of the system. We refer to this architectural notion as the *behaviour block concept*. In building with behaviour blocks, the overall behaviour of a robotic artefact / physical learning tool will emerge from the coordination of a number of physical building blocks that each represents a primitive behaviour (see Fig. 1, Right).

In order to utilise behaviour blocks, it is necessary to have primitive building blocks with certain properties. Each building block needs to have a suitable physical form and be able to process and communicate with its surrounding environment. The communication with the surrounding environment can be through communication to neighbouring building blocks and/or through sensing or actuation. In our project, we shall investigate the close analogy that emerges at this point with the use of dependencies. Informally, if a primitive behaviour can be viewed as like a definition of a spreadsheet cell, the behaviour block may then represent a whole family of interrelated definitions. Alternatively, a primitive behaviour may resemble an agent that redefines the value of spreadsheet cell in response to stimuli from the environment or actions on the part of the designer. The development of complex concurrent systems based on agents interacting through redefining variables within such families, as guided by observation and experiment of the application environment, is the characteristic idea behind EM. This affords the possibility of parallel exploration of virtual and actual worlds that can help to liberate the learning process.

The cognitive perspective

As our discussion of modern vs traditional AI shows, the trend in modern computing is towards dissolving the classical duality between brain and body. To some extent, technological developments - such as brain-mediated communication [] - oblige us to reconsider the established view. That the duality persists in the realm of technology-enhanced learning is self-evident from the terms of the TEL call itself: witness Pat Manson's reference [] to the 'false marriage' between 'logic and knowledge (L&K)' and 'logic and cognition (L&C)'. The superficiality of the learning involved in so much computer supported information processing in e-learning is widely acknowledged [Pratt,Roe,]. We attribute this to the fact that learning and knowledge has become divorced from learning and cognition. As in the case of complex adaptive systems, our vision for how intelligent tutor systems might evolve in the future can benefit from a better understanding of how brain and body are blended in learning.

All of the partners in our consortium are wrestling with this issue in different ways.

A very recent analysis of epistemological issues in mathematics education [Doerr+Pratt] highlights the tension between L&K and L&C (cf. WP2). A model of a situation can be 'exploratory', in that the learner interacts with an environment based on an underlying theory. Alternatively, it can be 'expressive', in that the learner is making a model to reflect their own interpretation of the situation as it emerges. Exploratory and expressive models are complementary ways of linking the phenomenological world with the world of mathematics, each with its own pedagogical difficulties. By 'phenomalising' mathematics [], the learner can access experiences in a virtual world that precisely reflect Newtonian mechanics. It remains unclear to what extent interaction in such a virtual world can connect with 'learning about Newton's laws' and with learning about the experiential world of real phenomena, where other factors beyond the scope of the idealised exploratory model pertain. By modelling their experiences, students start from the phenomenological arena, but it is unclear in what sense an appreciation of Newton's Laws can be the point of arrival, and how the validity of the expressive model that is being iteratively constructed is to be assessed (cf. the challenge faced by Naive Physics []). The notions of 'teaching' and 'learning' can be linked to the dual activities of trying to contextualise what can be formalised (as in exploratory modelling) and trying to formalise what is contextualised (as in expressive modelling).

From a pedagogical perspective, the distinction between L&K and L&C is reflected in learning strategies. L&K addresses learners who are reproduction-oriented and rely upon their short-term memory. By contrast, L&C relates to learners who are meaning-oriented; they may have a brittle short term memory but compensate for this with a richer slower elaboration strategy. Whereas formal languages and logics give us a good account of L&K, the choice of representations for studying L&C is much more problematic. In L&C, the focus is on the elusive activity with which learners engage in the ZPD - the zone of confusion (cf. WP4).

The key issue in this context is knowing how to make the connection between what is formalised and what is contextualised. This is our motivation for studying experiential learning as it is enabled and embodied in the construction of interactive artefacts (IAs). In this context, processes and techniques take the place of predicates, as in the study of concept maps [Piet] and woven stories [Piet and Erkki]. Through the power of association and embodiment, such expressive formalisms can evoke rich learning experiences. Even so, where giving useful accounts of phenomena is concerned, the problems of intersubjectivity and validation remain acute.

The novel concept of dependency that we shall explore in our project offers a radically different point of entry into the learning domain. Unlike a story or a behaviour, it is first and foremost apprehended in present experience. In its most primitive form, it expresses our expectations about change: how we orient a stick will dictate where its shadow falls. One step removed, it provides an explanation for state-as-experienced: the gnomon of the sundial no longer casts a shadow because the sun has gone behind a cloud. Beyond that, dependency mediates recognition of connection: the fact that the shadow falls here means that it is now noon. The relevance of Piaget's extensive treatment of causal thinking [] has yet to be explored, as has Gordon Pask's notion of conceptual entailment []. Some related themes have been addressed however: the sense in which a formal representation of an algorithm can be interpreted in experiential terms [WMB,JR,JES], and the way in which knowledge-based systems can be transformed to entailment meshes and viewed as IAs rather than as logical systems [cf Sisyphus exercise].

The above discussion motivates a thesis that is a useful focal point for our project: that EM enables experiential learning. This thesis will be critically appraised with specific reference to constructionism, and in specific learning situations that relate to students aged 9-15 who are studying complex phenomena. There is considerable informal evidence in support of our thesis from previous work [Kal ShowCase], but this has largely been in the context of working with UK students of computer science of unusually high ability, and has often been incidental to the main objectives of their model-building. The transposition of this work to another educational context will involve further development of our tools (WP6) and a more rigorous cognitive evaluation and validation (WP7). The activities involved in this process will create many opportunities for sharing expertise and interdisciplinary knowledge that will be of mutual benefit to all the partners.

The obligation that validation puts upon expressive models can be seen as the fundamental challenge to be addressed in technology-enhanced education, when we consider the implications for learning of the potential discrepancies between our 'real' and virtual worlds. This motivates a bolder and more contentious thesis: that EM embodies experiential learning. The crux of this thesis is to be found in the established connections between EM and William James's philosophical attitude of 'radical empiricism' [], which rests upon his contention that 'the directly apprehended universe needs ... no extraneous trans-empirical connective support' []. Our project is well-configured for exploring the arguments and finding the evidence to support and challenge this controversial claim.

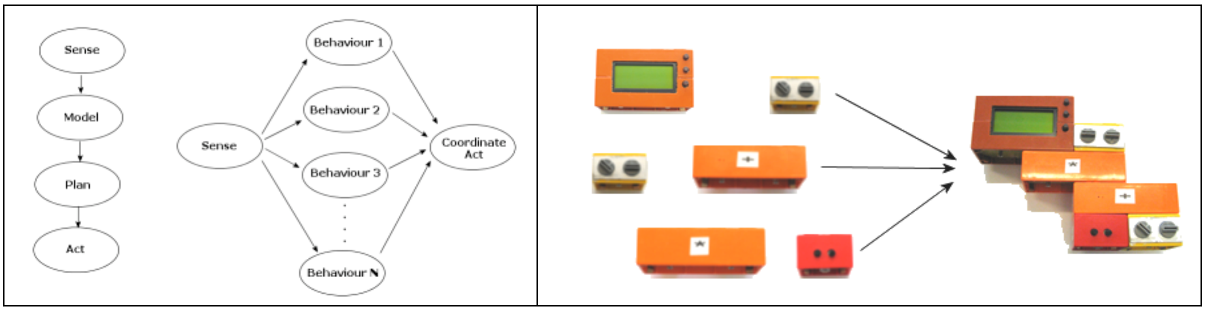


Figure: Left: the classical AI approach to robot control with a sense-model-plan-act cycle vs. the modern AI approach to robot control with primitive behaviours running in parallel. Right: A graphical representation of the behaviour block concept. Each building block represents both a *physical primitive* and a *functional primitive*, and when combined together, they will create an overall physical and functional structure. In more philosophical terms, the combination of the building blocks will create both the body and the brain.

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5. H. A. Simon, “The Sciences of the Artificial”, MIT Press, MA, 1969.
6. N. Nilsson, “A Mobile Automation: An Application of Artificial intelligence Techniques”, in Proceedings of the 1st International joint Conference on Artificial Intelligence”, pp. 509-520, 1969.
7. R. Pfeifer and C. Scheier, “Understanding Intelligence”, MIT Press, MA, 2001.
8. H. H. Lund, “Intelligent Artefacts.” In Sugisaka and Tanaka, editors, Proceedings of 8th International Symposium on Artificial Life and Robotics. ISAROB, Oita, 2003.
9. J. Nielsen, and H. H. Lund, “Spiking Neural Building Block Robot with Hebbian Learning.” Proceedings of IROS’03. IEEE Press, 2003
10. H. H. Lund, P. Marti, and V. Palma, “Educational Robotics: Manipulative Technologies for Cognitive Rehabilitation”. In Sugisaka (ed.) Proceedings of 9th International Symposium on Artificial Life and Robotics. ISAROB, Oita, 2004. **Best Contribution Award.**
11. P. Marti, and H. H. Lund, “Emotional Constructions in Ambient Intelligence Environments”. Intelligenza Artificiale, 1:1, 22-27, 2004.

B.3 Potential impact

Recommended length – three pages

(Describe the strategic impact of the proposed project, for example in reinforcing competitiveness or on solving societal problems. Describe the innovation-related activities. Describe the exploitation and/or dissemination plans which are foreseen to ensure use of the project results. Describe the added-value in carrying out the work at a European level. Indicate what account is taken of other national or international research activities.)

Our project has a specific educational focus but its potential implications are broad. There is already a body of informal evidence of the potential benefits that EM can bring to educational applications at a higher education level [KAL], and many other possible areas of applications have also been investigated. Our project will greatly enrich our understanding of both the methodological and technological aspects of EM, and provide more objective evaluation of its virtues and limitations as an enabling technology. Through the educational strands we shall be able to initiate a dialogue with the primary stakeholders: the learners, teachers and managers within schools, and those (now typically outside schools) who build educational software.

The principal benefit that will stem from wider exposure and dissemination of our research on IAs is an awareness of an alternative culture of software that in time can change the role of the educational software builder. This is only to be expected in view of our declared objective to integrate the roles of the learner, teacher and builder more closely in the true spirit of constructionism. Ideally, the teachers or even the learners can themselves be builders. Alternatively, the incremental evolution and customisation of IAs for use in schools may become so pervasive and routine that this role is carried out by a specialist builder within the school itself. A further possibility, which our project aims to address through developing a supporting community and infrastructure, is that such routine adaptation of IAs is carried out through collaborative interaction across the web.

In understanding the true nature of this vision, it is important to recognise the fundamental distinctions between the IAs we hope to develop and conventional programs. As of now, programs are for the most part polished objects sold as products designed to fulfill prescribed and specific functions []. Should a teacher wish to modify such a product, they have neither the technical prowess to make this modification, nor any recourse other than to request a new feature in the next release. By contrast, the kind of IA that we shall generate will always be open to revision throughout its development to and beyond the point of distribution. Unlike a typical software product, it will resemble a resource that can be used and adapted to many different purposes in a quite open-ended manner. For instance, should a teacher wish to modify some feature of the artefact in order to suit the specific need of a particular child in a particular situation as it arises, this will typically be possible. What is more, the manner in which the artefact itself is constructed will be so intimately linked to learning about the domain to which it refers that - either with a modest degree of specialist knowledge, or simply experience of interaction of the IA over a period of time - the teacher could make this modification without major difficulty.

Over and above this, rather than being like an object that we own, use in certain ways, and value for specific characteristics, an IA will resemble a place: somewhere to which (metaphorically) we come, that we can work in, where we can meet and share with others, can make our own without needing to exclude others. In this vision, the learning activity will come to resemble an exercise in concurrent engineering, where the perspectives of the teacher, the learner and the builder can be projected onto a single IA through interactive demonstration.

There is of course no question that this picture is something of an idealisation, but it is a vision for which we believe our previous work has already established proof-of-concept []. In so far as it is unrealistic, we expect many to address its shortcomings in the course of our project. What cannot be addressed in this fashion can be resolved by providing a suitable support infrastructure.

The image we have depicted is not to be confused with some kind of highly sophisticated and efficient intelligent teaching/learning automaton. The IA has no explicit intended function, only a current state. Though certain of its behaviours can be automated at will, to give the effect of traditional program execution, it passes through states that are meaningful in the sense that they are expressed as families of dependencies that correspond to families of observables and dependencies in the domain in which learning takes place. Most significantly, the states of the IA can be modified to reflect proper understandings and misapprehensions quite as easily, so that they can be used pedagogically to show the consequences of error in the spirit of a 'what if?' scenario. In interacting with such an artefact with a view to learning, there is necessarily some measure of unfamiliarity, and an associated need to encounter an initial difficulty. But, provided that the artefact is well-conceived, the difficulties it presents in use will reflect valid learning opportunities, and will correspond to useful insights about the learning domain.

From the learner's perspective, IAs are incrementally built up so as to embody relationships in the phenomenon being studied as they are encountered. Those relationships that persist throughout the learning process form the core of the IA, and typically become subject to validation in almost every subsequent interaction with the artefact. Of these relationships are faithful to the learner's experience, the validation of core relationships becomes unconscious, and will be only be challenged when the context for observation is changed or an exceptional situation is encounted. Building IAs in this way necessarily involves engagement with some parallel realm of experience, even if this is present only in the learner's imagination. When compared with downloading predigested information from the internet, or watching a TV programme, this promotes personal engagement that helps to stimulate imaginative and innnovative thinking.

scaffolding

cognitive layering / quality of experience reflected

Building

The development of the behaviour blocks concept allows users to create both physical functional and conceptual structures, as indicated in [8, 9, 10, 11]. This lays the basis for the conception of ‘programming by building’, in which programming of a specific behaviour simply consists of building physical structures known to express that specific behaviour. In this way, we shall move away from programming the artefacts with traditional programming languages, and instead provide methods that allow people to construct complex behaviours without the need for any a priori knowledge about programming languages. If suitable principles for designing and constructing blocks can be developed, it may even become possible to remove the host computer (e.g. a PC) that is traditionally used in this context. There are strong parallels here with the way in which virtual IAs can be built by programming using families of dependencies. The work to be carried out in our project towards integrating the construction of behaviour blocks with that of virtual IAs will help to evaluate what is feasible in this regard. Possible applications for such a technology include creating suitable human-robot interfaces for industrial manipulation robots.

Through linking building with behaviour blocks to modelling with dependency, we shall need to elaborate on how construction and configuration of building blocks can represent a conceptual structure, and be used at different scales and in different contexts. By giving physical embodiment to conceptual structure in a way that is customised to a specific environment, behaviour blocks can serve dedicated functions that a PC, despite its vastly superior computational power, cannot. Positive results were found when working with IAs of this nature in a linguistic scenario with children with dyslexia at a hospital in Siena (?). By extension of such principles, behaviour blocks could be developed to support creative processes in developing narratives and in externalising emotions associated to 'living entities'. As a further application of this concept, tangible tiles have been developed as small, distributed units with processing and communication capabilities that can be utilised anywhere in the modern city space for enhancing play opportunities and promoting physical exercise. These are conceived as just the first step towards implementing a modular robotics technology for larger scale applications to which the collaboration within this project will contribute.

In the construction process, the intimate and explicit nature of the interaction between the builder and the behaviour blocks (when contrasted with the largely private and cryptic nature of much conventional programming activity) opens up possibilities for investigating learning activity in a fashion that is not intrusive. This is analogous to the auditing of modelling with dependency that we propose to introduce and empirically evaluate in the course of our project, and may provide a useful source of new insight into learning in the ZPD. It also prepares the ground for other research questions: Can an individual learnerís behaviour be recognized when constructing and interacting with the building blocks? And can the building block artefacts be adapted in order to increase/maintain the overall level of engagement?

B.3.1 Contributions to standards

Recommended length – one page
(Describe contributions to national or international standards which may be made by the project, if any.)

Educational software standards

When software is seen as embodying a theory, the only solution to problems of integration appears to be to unify theories, which isn't always feasible because of conflict or complexity

the imposition of standards is a natural consequence of this

premature to impose standards where our grasp of theory is so unsure (cf. trying to impose standards on the interactions of Faraday and his contemporaries etc) - extraordinary [absurd?] standard classification of learning objects as evidence of this

developing software in a way that is not theory-led can overcome this problem: witness the experience of the BBC and the EU in relation to broadcasting standards

not to deny the importance of discipline, but standards should emerge from fuller understanding, in the same way that theories post-date prolonged experimenal work

Something about standards for modelling with dependency e.g. on how to specify definitive notations

Addressing the rationale for standards

Have an EU ideal of diversity within unity. Standards are perceived as a way to bring the unity, and to promote intercommunication. Danger in this is loss of diversity. Parallel to be drawn with how English may displace other languages - want to simultaneously preserve cultural diversity and stimulate intercommunication ...

... making two different EM [RADICAL] models based on different modes of observation and building dependencies to connect them has just such impact. Envisage that with wider adoption and dissemination of our methodology this can impact on the open source model for development. Not just open access to all who are technically literate enough to understand how to engage with a complex artefact on its own terms, but allowing those with partial understanding to explore engagement with an artefact, to adopt it as a resource, or to link it to their own personal related artefacts. In this way an "open source resource for the mind". [Refer to the CS405 web submissions?]

B.4 The consortium and project resources

Recommended length – five pages

(Describe the role of the participants and the specific skills of each of them. Show how the participants are suited and committed to the tasks assigned to them; show the complementarity between participants. Describe how the opportunity of involving SMEs has been addressed. Describe the resources, human and material, that will be deployed for the implementation of the project. Include a STREP Project Effort Form, as shown below, covering the full duration of the project. Demonstrate how the project will mobilise the critical mass of resources (personnel, equipment, finance…) necessary for success; and show that the overall financial plan for the project is adequate.)

Our consortium is a rich mix of academics and computer professionals spanning a wide range of disciplines and experience. We have in common a deep interest in the nature of learning, and a suspicion of the simplistic connotations that the term has acquired in some variants of e-learning. Our aspiration is to complement traditional tools of educational technology with IAs that have the power to engage the learner more deeply in the ZPD, to reflect the personal nature of learning activity, to take account of the contextualised nature of learning, and to embrace the modern AI paradigm that favours embodiment rather than abstraction. The viewpoints represented in this consortium include computer science, computer systems engineering and AI, cognitive science and mathematics with reference to how these subjects relate to education, history and philosophy. It will be led by a research scientist who has been working in the field of interactive television, and who has himself developed tools that exploit dependency to overcome the problems of cross-platform digital broadcasting. The consortium also includes a senior figure from a [the] leading UK educational software company, who has a strong interest in the potential of the principles represented in this project and will act as a commercial advisor.

significant that whilst the mainstream culture of educational technology is heavily consolidated behind a common theoretical understanding, those who criticise this are dispersed and tend to be on the fringes of academic departments - hence consolidation is important, furthermore establishing a common thesis (if this is can be legitimised by this project) will be most helpful in giving greater influence and authority to voices that need to be heard

project is a form of constructionist learning itself on the European scale

[mobility] using this thesis about learning as a way of bringing several research groups interested in learning and cognition together into a constructive dialogue

Several research interactions amongst the leading participants are already well-established, and will stand to benefit greatly from the proposed collaboration. Sutinen, Pratt and Joy have There are a number of well-established

Joint publications Sutinen, Lund and Kommers

IMPDET

Beynon and Pratt via Roe

There has been independent collaboration between Roe and postgraduates working with KC at Joensuu, including Marjo Virnes [].

Summer Schools at ICALT 2004

Sutinen and Joy have collaborated under the Socrates program

Sutinen and Beynon at summer school ICALT 2005

Sutinen and Lund have done joint research in Tanzania

Kommers organising ICALT 2006 in Twente

STREP Project Effort Form
Full duration of project
(insert person-months for activities in which partners are involved)

Project acronym -

	Partner 1 short name	Partner 2 short name	Partner 3 short name	Partner 4 short name	Partner 5 short name	etc	TOTAL PARTNERS
Research/innovation activities							
WP name							
WP name							
WP name							
etc							
Total research/innovation							
Demonstration activities							
WP name							
WP name							
WP name							
etc							
Total demonstration							
Consortium management activities							
WP name							
WP name							
WP name							
etc							
Total consortium management							
TOTAL ACTIVITIES							

B.4.1 Sub-contracting

Recommended length – one page

(If any part of the work is foreseen to be sub-contracted by the participant responsible for it, describe the work involved and explain why a sub-contract approach has been chosen for it.)

B.4.2 Other countries

Recommended length –one page

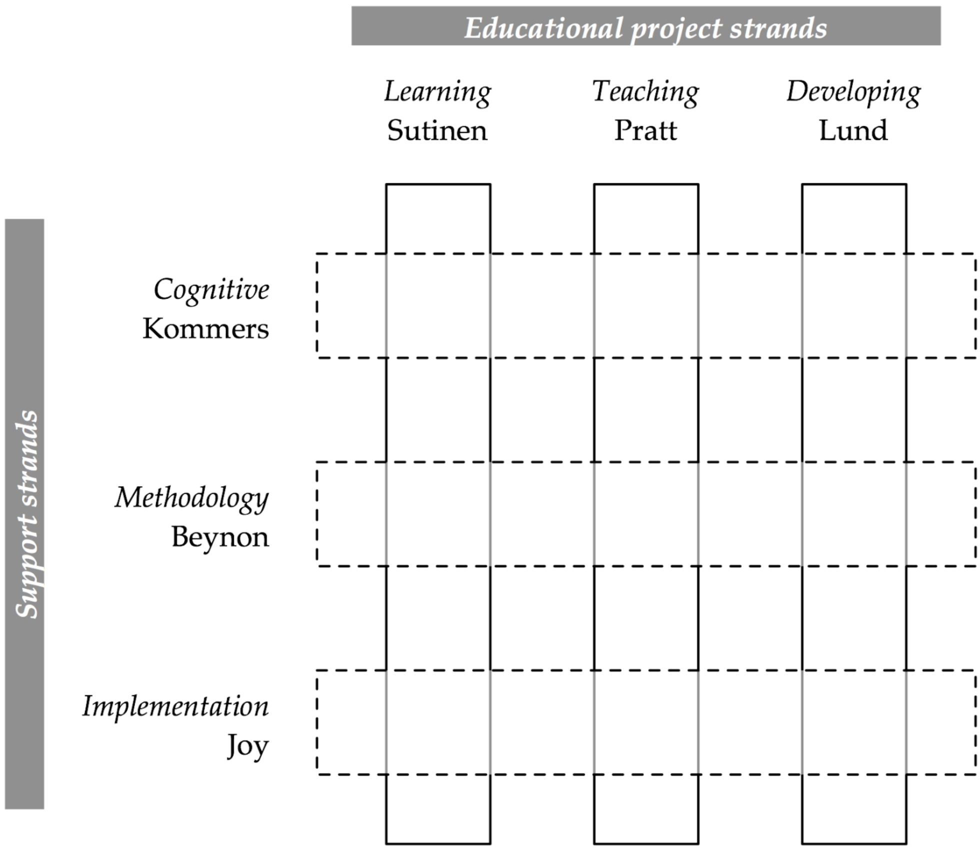
(If one or more of the participants is based outside of the EU Member and Associated states, explain in terms of the project's objectives why this/these participants have been included, describe the level of importance of their contribution to the project.)

B.5 Project management

Recommended length –three pages

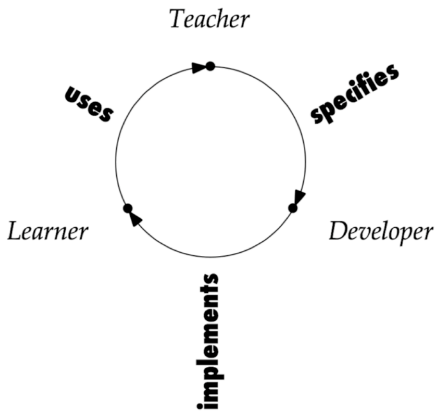
(Describe the organisation, management and decision making structures of the project. Describe the plan for the management of knowledge, of intellectual property and of other innovation-related activities arising in the project.)

We are proposing a matrix management model operating under a project director who has overall responsibility for project management etc. *[We think that having such a director would help to make our proposal more viable and credible from a management point of view.]*

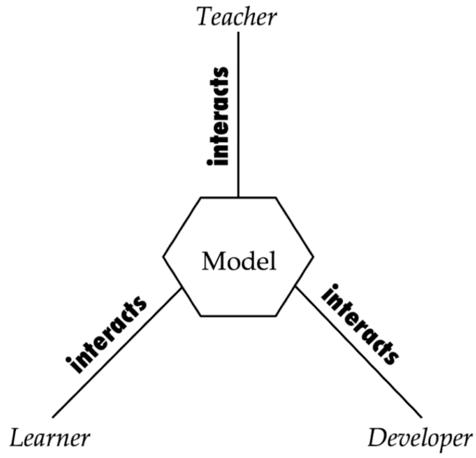


The above diagram depicts the matrix for the management. This suits our purpose because there is more than one orientation to the activities of the project (viz. deliverables and demonstration activities of the educational research strands + advancement of the methodology and tool refinement and evaluation), and there is a need to share human resources, since there are relatively few people trained in the RADICAL methodology and familiar with the tools hitherto. The project director to act as coordinator of the work of the project, and chair for meetings / arbiter in the case of controversy. (cf Project Management, Harvey Maylor, Prentice Hall 3rd ed 2003, p223-4). So expect to have at least three people (possibly including the leader of the strand) in each educational research strand. In particular: will match Pratt with Beynon (methodology), and equip with two co-researchers for cognitive studies and implementation, similarly, Sutinen with Kommers (cognitive studies), and Lund with Joy (implementation) + 2 researchers. [*estimated costs will then be or* *the order of 400K euros for each of Joensuu, Adaptronics, CeNTRE – cf Dave Pratt's provisional budget for CeNTRE*].

A major objective of the project is integrating the roles of learning, teaching and building that are performed by all of the stakeholders (students[learners?], teacher and developers) in the constructionist learning setting. Aim to make the case for getting learning, teaching and building to converge:



Traditional constructivist framework



The RADICAL constructivist framework

There are a number of operational issues to be addressed here: regarding location, coordination and monitoring, decision-making structures, and the detailed role of the Project Manager/Director. [There may be scope here to investigate how certain aspects of collaborative design within a dependency-based framework might operate at a meta-level in project interaction cf. a model for concurrent engineering proposed in EM papers + Cartwright's vision for collaborative geometric modelling.]

Also don't think we have enough people to make things credible just yet (looking at other successful proposals) – need to discuss this in proposal also? Need to include SBR if possible!

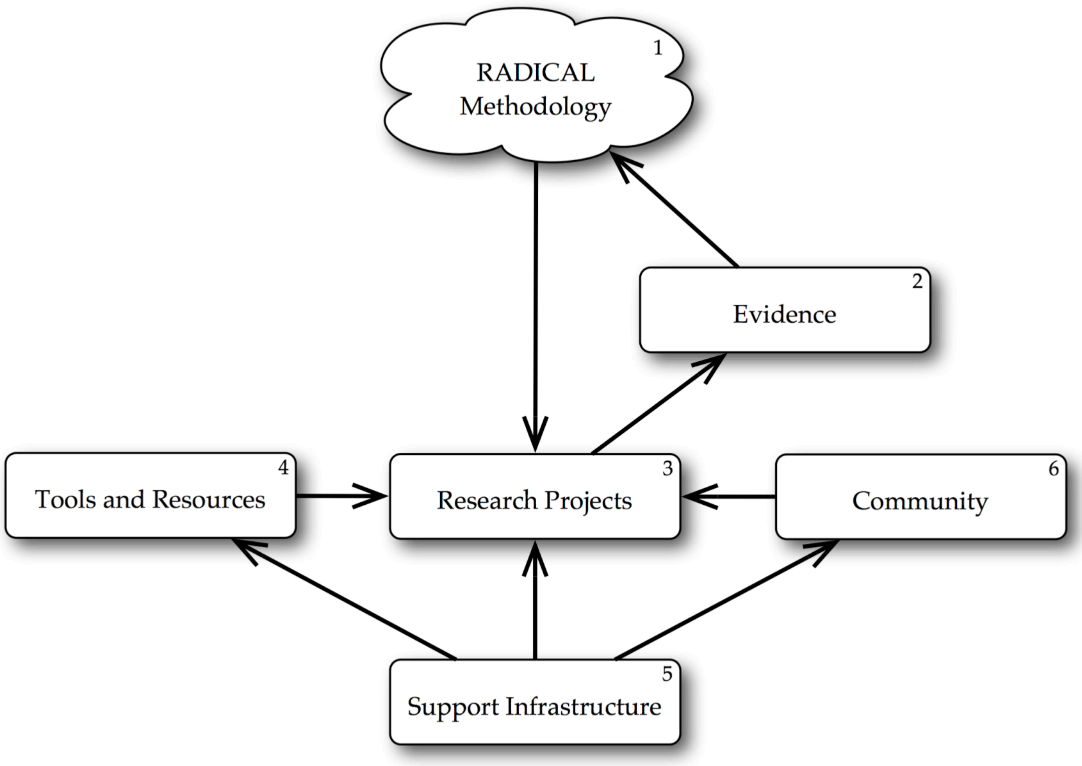
B.6 Detailed implementation plan

This section describes in detail the work planned to achieve the objectives for the full duration of the of the proposed project. The recommended length, excluding the forms specified below, is up to 15 pages. An introduction should explain the structure of this workplan plan and how the plan will lead the participants to achieve the objectives. The workplan should be broken down according to types of activities: Research, technological development and innovation related activities, demonstration activities and project management activities. It should identify significant risks, and contingency plans for these. The plan must for each type of activity be broken down into workpackages (WPs) which should follow the logical phases of the project, and include management of the project and assessment of progress and results

The number of workpackages used must be appropriate to the complexity of the work and the overall value of the proposed project. Each workpackage should be a major sub-division of the proposed project and should also have a verifiable end-point - normally a deliverable or an important milestone in the overall project. The planning should be sufficiently detailed to justify the proposed effort and allow progress monitoring by the Commission – the day-to-day management of the project by the consortium may require a more detailed plan)

a) Detailed implementation plan introduction

(explaining the structure of this plan and the overall methodology used to achieve the objectives)



b) Work planning, showing the timing of the different WPs and their tasks

(Insert Gantt chart or similar)

c) Graphical presentation of the components, showing their interdependencies
(Insert Pert diagram or similar)

d) Detailed work description broken down into workpackages:

(Workpackage list, use Workpackage list form below)

Workpackage list

Work-package No[1]	Workpackage title	Lead contractor No[2]	Person-months[3]	Start month[4]	End month[5]	Deliv-erable No[6]
	TOTAL					

[1] Workpackage number: WP 1 – WP n.
[2] Number of the contractor leading the work in this workpackage.
[3] The total number of person-months allocated to each workpackage.
[4] Relative start date for the work in the specific workpackages, month 0 marking the start of the project, and all other start dates being relative to this start date.
[5] Relative end date, month 0 marking the start of the project, and all ends dates being relative to this start date.
[6] Deliverable number: Number for the deliverable(s)/result(s) mentioned in the workpackage: D1 - Dn.

(Deliverables list, use Deliverables list form below)

Deliverables list

Deliverable No[7]	Deliverable title	Delivery date[8]	Nature[9]	Dissemination level[10]

[7] Deliverable numbers in order of delivery dates: D1 – Dn
[8] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.
[9] Please indicate the nature of the deliverable using one of the following codes:
R = Report
P = Prototype
D = Demonstrator
O = Other
[10] Please indicate the dissemination level using one of the following codes:
PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

(Description of each workpackage, use Workpackage description form below, one per workpackage)

Workpackage description

Workpackage number **Workpackage title** **Participant id** **Person-months per participant**	**Start date or starting event:**

Objectives

Description of work

Deliverables

Milestones[11] and expected result

[11] Milestones are control points at which decisions are needed; for example concerning which of several technologies will be adopted as the basis for the next phase of the project.

B.7 Other issues

No recommended length – depends on the number of such other issues which the project involves

B.7.1 Ethical and gender issues

(If there are ethical or gender issues associated with the subject of the proposal, show they have been adequately taken into account - indicate which national and international regulations are applicable and explain how they will be respected. Explore potential ethical aspects of the implementation of project results. Include the Ethical issues checklist. See Annexes 3 and 4 of the Guide for Proposers for more information on these issues.)

We will follow the standard practice of seeking permission from parents of students who may be involved in the project. We will also seek permission from the school management. Parents and schools will be informed about nature of the project and its aims. It will be explained how the findings will be used. Children and teachers will not be identifiable from disseminated information. We will also seek permission to use digital photography and videotape, subject to the accepted practice within the countries involved. Photographs and tapes will normally only be used internally within the project for analysis purposes. Where material is used in dissemination the children and teachers will not be identifiable. No children or schools will be used where full permission is not granted.

Ethical issues checklist

Table A. Proposers are requested to fill in the following table

Does your proposed research raise sensitive ethical questions related to:	YES	NO
Human beings		
Human biological samples		
Personal data (whether identified by name or not)		
Genetic information		
Animals		

If you answer "YES" to any of the above, please include in your proposal section B7.1 the more detailed version of Table A ("Crucial information") obtained from: http://europa.eu.int/comm/research/science-society/ethics/rules_en.html and also incorporate in section B.7.1 and in other appropriate parts of your proposal comments corresponding to the detailed instructions given in sections C-D at the above address

Table B. Proposers are requested to confirm that the proposed research does not involve:

- Research activity aimed at human cloning for reproductive purposes,
- Research activity intended to modify the genetic heritage of human beings which could make such changes heritable[12]
- Research activity intended to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer.

	YES	NO
Confirmation : the proposed research involves none of the issues listed in Table B		

Further information on ethics requirements and rules are given at the science and ethics website at http://europa.eu.int/comm/research/science-society/ethics/ethics_en.html

[12] Research relating to cancer treatment of the gonads can be financed

B.7.2 Other EC-policy related issues

No recommended length – depends on the number of such other issues which the project involves

(Are there other EC-policy related issues, and are they taken into account? Demonstrate a readiness to engage with actors beyond the research to help spread awareness and knowledge and to explore the wider societal implications of the proposed work; if relevant set out synergies with education at all levels.)