Deductive Framework for Math-oriented Collaborative Teaching Environments
Acronym: DEDUCATION
Small or Medium-scale focused Research Project (STREP)
ICT Call 8: FP7-ICT-2011-8

Date of Preparation: January 17, 2012

Work program topics addressed: ICT-2011.8.1
   b1) Educational technologies for science, technology and maths.

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Abstract

Although traditional mathematics education remains very conservative with respect to the systematic use of computers in education, the latter offers great potential: partially autonomous, explorative learning, where individual, interactive experiences can open new ways for pupils and students. Technologies for personal, computer-supported tutoring systems, personal research and teaching environments (PRTEs), and edutainment-like systems are of major importance for leveraging new teaching methods as well as reaching new social strata of pupils and students.

Recently and largely unnoticed in public, applications in science and technology drove the development of automated and interactive theorem proving technologies, which have become of major importance for mathematics and computer science. Although based on expressive logical foundations and implemented in a highly trustable way, and although used in some scenarios roughly similar to mathematical tutoring systems, their potential for a wide-spread education technology is unexplored: beyond proving theorems, theorem provers can manage formal content, check its logical consistency, and verify given problem solutions.

This research project will extend an existing interface for modern theorem proving systems to an implementation platform for domain-specific PRTEs. On this platform, a family of PRTEs will be implemented covering the area of interactive mathematical textbooks, teaching environments for algebra, logic and geometry, engineering training programs, programming teaching environments, logical games; for short, teaching activities based on problem solving strategies within a formally defined context. Our proposal emphasises incremental solution checking and includes an infrastructure for collaborative learning and teaching as well as interfaces to existing reporting and learning management systems. Chosen reference PRTEs will be evaluated in empirical studies in European schools and universities.

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<th>Full Form</th>
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<tr>
<td>ANR</td>
<td>Agence Nationale de Recherche (France)</td>
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<tr>
<td>ATP</td>
<td>Automated Theorem Proving</td>
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<tr>
<td>CAS</td>
<td>Computer Algebra System</td>
</tr>
<tr>
<td>DFG</td>
<td>Deutsche Forschungs Gemeinschaft (Germany)</td>
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<tr>
<td>DGS</td>
<td>Dynamic Geometry Software</td>
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<tr>
<td>GATP</td>
<td>Geometry Automated Theorem Proving</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
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<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
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<tr>
<td>ITP</td>
<td>Interactive Theorem Proving</td>
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<tr>
<td>LCF</td>
<td>Logic of Computable Functions</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
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<tr>
<td>PIDE</td>
<td>Prover IDE</td>
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<tr>
<td>PLE</td>
<td>Personal Learning Environment</td>
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<tr>
<td>PRTE</td>
<td>Personal Research and Teaching Environment</td>
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<tr>
<td>TP</td>
<td>Theorem Proving</td>
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<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
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1 Scientific and/or technical quality, relevant to the topics of the call

1.1 Concept and Objectives

Current issues in mathematics and science education. In addition to being one of the most fundamental sciences underpinning innovation, science and technology, mathematics provides reasoning and thinking tools that all citizens need in their everyday life. The importance of mathematics is made explicit in the European Framework of Key Competences [60], where “mathematical competence and basic competences in science and technology” is listed as one of the eight key competences describing the knowledge, skills and attitudes that are essential in a knowledge society.

During the last decades, there has however been a drop in young people’s interest in mathematics and science [63]. This is alarming not only because it constitutes a threat to Europe’s capacity to create innovations and produce high quality research, but also as it puts individual citizens’ ability to cope in a society that becomes more and more dependent on science, technology, engineering and mathematics (STEM) at risk. This issue has been acknowledged by projects and initiatives improving science and mathematics curricula and teaching standards on several continents, e.g., “Science for All Americans” [64], Science in the New Zealand Curriculum [55], the Pan Canadian Science Project (Council of Ministers of Education 1997), the SINUS-project [13] as follow-up action to TIMMS in Germany and the OECD Programme for International Student Assessment (PISA) [57].

Different reasons for the lack of interest in mathematics can be found: self-perceived feelings of “not being good at mathematics”, finding mathematics difficult, poor previous achievement in mathematics and finding mathematics “of no use” [53]. To improve the situation, teachers are generally recommended to implement pedagogical strategies that motivate and engage students, as different teaching approaches can improve attitudes and increase attainment levels [58]. Today, one of the most popular ways of “renewing” education is to integrate computers and software to a higher extent. Studies (e.g., [46]) imply that computer use by the teacher gets positive reactions among students, who appreciate that teachers use computers and other technologies that play a big role in their life outside of school [73]. Students generally also express more positive feelings when using computers compared to when given other tasks to do [14]. Computer support also makes it easier to create tailor-made learning material and offer flexible education; this is an important aspect as each learner is different and has different needs [58]. In summary, well designed computer use in education has potential for increasing students’ interest and motivation for learning the subject at hand.

The use of computers in mathematics education has, however, not been as straightforward as in other subjects, e.g., due to difficulties in presenting and producing mathematical text electronically. Nevertheless, as technology has moved forward, a multitude of innovative and educationally sound software tools have been developed. Still, much is to be done. The goal of DEDUCATION is to use emerging technologies to push educational mathematics software beyond the state of the art by developing educational software components called personal research and teaching environments (PRTEs), a kind of mathematical tutoring systems. Following a common definition [65, 66, 67], such systems provide an environment for research and teaching that is under the control of a researcher/teacher/lecturer. A PRTE is equivalent to a personal learning environment (PLE), but PRTEs also let students participate in knowledge construction. In DEDUCATION modern automated and interactive theorem proving (ATP and ITP) systems will be used to provide students and teachers with a family of innovative, collaborative and highly useful PRTEs.

Emerging technologies for the mechanical checking of mathematical content. In recent years, applications in science and technology drove the development of automated and interactive theorem proving technologies, which have become of major importance for computer-science and in all areas of mathematics. ATP and ITP systems have been used for verifying hardware [1, 35], industrial software [43, 45], and very large mathematical proofs [6, 37, 39], where the conventional peer-review process is hitting a complexity barrier. Of particular interest for this proposal are ITP systems such as Coq [28] and
Isabelle \cite{81} going back to the seminal LCF system \cite{38} (from 1979), which has pioneered key principles like \textit{correctness by construction} for primitive inferences and definitions, \textit{free programmability} in user-space, and \textit{toplevel command interaction}. Both Coq and Isabelle have elaborated the prover architecture over the years, driven by the demands of sophisticated proof procedures, derived specification mechanisms, large theory libraries etc.

Since around 2005, the ATP and ITP research communities were faced with an exponential growth of parallel CPU cores and the need to get real performance from it. This forced in particular the ITP research community to substantially revise their system architectures and their underlying computation models for supporting \textit{parallel and concurrent applications} \cite{52,77,78,80}. Beyond traditional processing of proof scripts as sequence of proof commands, and batch-loading of theory modules, there is a large space of possibilities and challenges for pervasive parallelism to be exploited by increasingly parallel consumer hardware. This affects many layers of each prover system: basic computational structures, inference kernels, tactical programming interfaces, proof command languages, and interactive user-interfaces. For the user, this translates into larger theory developments and new application domains.

In parallel to this development, the design of ITP systems evolved from \textit{proof systems to formal document management} systems, where the documents consist of definitions, theorems, proofs, code, computations, and prose text containing formal references to them. This trend to a document-centric view (e.g. \cite{79}) met the trend to pervasive parallelism in the most advanced ITP systems like Isabelle \cite{80}. This allows for \textit{asynchronous} techniques to check the formal consistency and evaluation of formal documents, which can describe all sorts of entities ranging from standard mathematics over program semantics to modeling languages in computer science. This means that user-interfaces can follow the paradigm of \textit{continuous build — continuous check} known from integrated development systems (IDEs) for generic document models allowing for semantic checks in a wide range of applications.

The ability of leading ITP systems to check documents asynchronously, requiring that the inference kernels can perform many inference steps in different logical contexts, enables these systems to new application domains based on the semantic checking of \textit{distributed} documents that were developed collaboratively by a large number of users. Combined with new technologies for developing web applications, such as HTML5 which includes drag-and drop user interaction and drawing canvas elements for animation, and the mathematical markup language MathML, this paves the way for new cloud-like organisation forms and moreover the integration of advanced formal systems into the \textit{Future Internet} (FI).

\textbf{The perspective of personal research and teaching environments based on TP technology.}

Although based on expressive logical foundations and implemented in a highly trustable way, and although \textit{used} in some scenarios roughly similar than mathematical tutoring systems, the potential of leading ITP systems for a wide-spread education technology is unexplored. As two cases in point, we consider two PRTE example scenarios in more detail, the mathematical textbook and Euclidian geometry.

\textit{The Mathematical Textbook}. Nowadays, it is straightforward to present a mathematical textbook as a hyper-text. A plethora of applications exist, usually including solution sheets for common exercises like:

\begin{align*}
7x^2 - 6x &= 0 & \text{\{factoring } x\text{\}} \quad (1) \\
\equiv x(7x - 6) &= 0 & \text{\{zero product rule\}} \quad (2) \\
\equiv x &= 0 \lor 7x - 6 = 0 & \text{\{calculations\}} \quad (3) \\
\equiv x &= 0 \lor x = \frac{6}{7} \quad (4)
\end{align*}

The available applications, however, lack the possibility to \textit{explore} solutions. In contrast, ITP technology offer learners the potential to explore this kind of proof activity themselves, incrementally, line-by-line, and to have each step checked as well as guided by hints provided by the system. When equipped with theories for arithmetics, linear algebra, calculus, and so on, as well as with didactic machinery to provide
hints and assessment, ITP systems can provide a fine-grained didactic support that otherwise only a private tutor could offer. When organized as web applications, mathematical textbook PRTEs can be implemented as cloud services which provide e.g. an entire country with scalable access to the system.

*Euclidian Geometry.* ITPs are not restricted to algebraic or symbolic reasoning. ITPs can deal with essentially all kind of theories that have a formal underpinning, let it be geometry, programming, system modeling in UML or logical games (e.g. riddles like sudoku). Mathematics benefits from linking abstract concepts with their concrete models and visualizations, thus creating an environment where experiments can be made. In a Euclidian geometry PRTE (as shown in Figure 1), users can move animated geometry figures around, and, while the whole picture is updated, they can check whether the status of a conjecture that they are examining is affected by their actions. ITP technology can both check the error-prone side conditions of this “intuitive reasoning” (degenerate cases in which the conjecture fails are usually not so trivially established by random mouse clicks), but also present the user with both views kept in sync, the visual constructive aspect as well as the logical proof.

Of course, the question arises if this variety of different application domains can and should be addressed by a uniform ITP technology. One might object that not only the underlying theories, but also the symbolic computations on them are far too different for a practically viable uniform solution, in particular if semantic checking in PRTEs is done on a very large scale (e.g. hundreds of users relying on a server cluster).

In this respect, it is instructive to consider a system architecture diagram of the envisaged family of PRTEs in Figure 2: In leading edge ITP systems like Isabelle [81] and Coq [28], many special-purpose ATPs have been integrated as tactics. When executed, parts from the current proof state are extracted, converted, and fed into an external ATP, the proof of which is subsequently re-interpreted as composition of primitive inferences in the ITP kernel. This holds for prominent systems like Z3 [29], SPASS [76], E [71]. A substantially simpler, but logically less trustworthy integration uses external proof procedures as oracles, logging their use in the resulting theorems; this way, integrating computer algebra systems (CAS) or special purpose provers in the domain of geometric reasoning is nowadays a routine task. In an interactive setting, it is preferable to use ATPs not directly, rather via tactics in an ITP environment that has infrastructure to generate human-readable feedback in form of formula display including uniform decoration with markup (such as colors, tooltips, auto-completion, and so on) and adequate representations of mathematical symbols (see Figure 2 for the proposed architecture). Such tactics internally using external ATP systems can be arbitrarily mixed with built-in tactics of these provers; combined with user-programmed code, this represents a flexible and
powerful infrastructure for symbolic computations necessary, for example, to produce hints for a next-step-guidance.

For Isabelle and Coq, there is a framework — the PIDE Framework — which allows for abstract communication with them on a system level. This means that it is possible to communicate an entire document as well as incremental updates on them by a programming interface. A key concept provided by the PIDE Framework is a (generic) document model; roughly speaking this is a directed acyclic graph of sequences of commands (also known as development graph consisting of theory nodes, each containing a sequence of statements with definitions, code and proofs). Documents are generic in the sense that the PIDE Framework is ignorant on the syntactic form of commands (the underlying prover decides if a command is syntactic correct). In the case of Isabelle, the PIDE Framework is already existing as part of the system distribution since Isabelle2011; it is currently generalized in the ANR Paral-ITP project (see http://paral-itp.lri.fr/) such that the same framework will work for both Coq and Isabelle.

The most intriguing aspect of the PIDE Framework, however, is its ability to evaluate (versions of) documents in an asynchronous way, i.e., a document is decorated with information (errors, warnings, types of each sub-term in the display, the logical status of proof attempts, executable code, the results of evaluations, etc.) which is added to the document in a non-linear, highly parallel way. This ability for asynchronous semantic checking of formal documents actually gave PIDE its name: Framework for Prover IDEs.

Undeniably, general purpose GUIs over the PIDE Framework and the logics used in the underlying ITP systems are way too general and complicated for direct use in science and mathematics education. However, the PIDE Framework allows for the integration of ITP technology into special purpose, Java-based applications and libraries (e.g., Swing or JavaFX). Moreover, PIDE allows for developing rich client applications (native application) based on existing technologies such as Eclipse, Netbeans or the Euclidian geometry PRTE GeoGebra [40]. This paves the way for PRTEs with both clean logical foundations as well as problem-specific symbolic computations for specific high-level hints, next-step-guidance and student assessment. The approach also encompasses visual presentations of problems and results in form of diagrams and animations. With respect to programming-oriented PRTEs, it is straightforward to reuse the existing Isabelle jEdit interface, a rich client interface for the interactive proof exploiting the asynchronous

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1 A typical user-session of Isabelle may involve many thousands of evaluation tasks that are associated with incremental document processing. This can be mapped efficiently to a small number of worker threads that is correlated with the number of hardware cores on parallel hardware.
evaluation of the underlying document model by the *continuous build — continuous check* paradigm. Moreover, due to its characteristic asynchronicity and genericity the PIDE Framework is crucial for the development of *web applications*, which may revolutionise the way in which PRTE software is organised and distributed in schools and universities. On the one hand, PRTEs that are realized as web applications foster especially a collaborative work style, even among distributed teams. On the other hand, developing PRTEs as web applications allows for offering PRTEs as hosted *on-demand* solutions. Such an on-demand offering will also provide easily adaptable web services and, moreover, opens new national and European markets for science education software.

Beyond the foundational logics aspect, the uniform treatment of user interaction in PRTE scenarios via a document model also holds the key for the perspective of a *collaborative* PRTE: Entire documents will contain theories, code, and local solution attempts, which makes it possible for different user groups to access, modify and extend them. Thus, different user groups like technical administrators, PRTE developers, teacher groups and pupils are able to work on the same source with different access rights on the same technical infrastructure. This leads to collaborative infrastructures like distributed version management of formal content, which can immediately be checked semantically. Thus, the generic DEDU-framework and its instance PRTEs are not just a scholar’s electronic portfolio, but a place to share and contribute with a community at large.

Via its control over the increments by the user, a uniform document model also provides the raw data for PRTE-specific *learning metrics and an assessment infrastructure*: Using PRTE specific abstraction functions which were executed on the DEDU-framework while processing the increments of its user sessions, the increments can be used to count and measure the quality of hints for users, the number of errors, potentially the degree of completeness of partial solutions, etc.

**The research objectives.** This proposal advocates the idea that ATP and ITP systems can be extended to a platform for the implementation of specific PRTEs in the area of interactive mathematical textbooks, teaching environments for algebra, logics and geometry, engineering training programs, programming teaching environments, logical games and other teaching activities based on problem solving strategies within a formally defined content. ATP and ITP techniques are used to check (partial) solutions of pupils and students and to provide hints for problem solutions.

Since established ATP and ITP systems are highly complex — typical ITPs usually address specialized computer science engineers or PhDs with a mathematical background — we suggest to:

- **OBJ.1:** Build a core framework supporting incremental solution checking and elaboration of mathematical derivations and modeling activities based on an ITP. This includes an infrastructure for user-guidance, faulty proof-attempt analysis and student assessment.
- **OBJ.2:** Develop an infrastructure for collaborative learning in potentially distributed teaching environments. This infrastructure is based on the DEDUCATION Framework (OBJ.1) and extends the framework with support for distributed content as well as distributed applications. This includes the support for versioning and merging of distributed formal content as well as load-balancing in multi-user scenarios.
- **OBJ.3:** Provide a web framework to develop applications that interact with the DEDUCATION framework (OBJ.1 and OBJ.2). This involves high-level support for textual and graphical representation and interaction.
- **OBJ.4:** Build a suite of PRTEs (use cases) offering presentation methods (GUIs) and teaching methodologies adapted to a problem domain and the addressed target group. A particular emphasis is put on systems offering a visual *view* on reasoning and deduction. Example PRTEs can be native applications, web applications, or both.
- **OBJ.5:** Perform an empirical evaluation based on carefully chosen reference examples in schools and universities in several European countries. This involves both the development of formal assessment
criteria based on user-interaction with the framework OBJ.1–4 as well as their validation in carefully
designed field-studies.

• OBJ.6: Scientific dissemination and industrial exploitation of results. The objective is to successfully
disseminate DEDUCATION results via various dissemination channels including academic publica-
tions, events and training. In addition, the industrial exploitation of the project results via project part-
ners or knowledge transfer will be pursued to contribute in particular to the viability of the web-based
e-learning systems, as well as improving the European industrial competitiveness in this market.

In our view the crucial aspect of interactive teaching methods (in contrast to conventional textbooks) is
that learners may try — independently of a trainer — different solution strategies and are encouraged to
individual experimentation in modeling. Our approach also allows more edutainment-like systems with
automatically generated problems of a limited domain (sudokus, beam-of-light-like games), where even
partial solutions are checked by the framework.

Relevance to the topics addressed by the call. The DEDUCATION project fits naturally into the
objectives of the FP7-ICT-2011-8.1: Technology-enhanced learning. The EC envisions as target outcome
for STREPs, b1) Educational technologies for science, technology and maths (our principal target), a) Tech-
nology Enhanced Learning systems endowed with the capabilities of human tutors, and d) Computational
tools fostering creativity in learning processes, in particular:

• b1): Supporting students to understand and construct their personal conceptual knowledge and mean-
ing of scientific, technological and/or mathematical subjects.

• b1): Technological solutions should take the learners through the complexity of a subject, activating
and feeding curiosity and reasoning [⋯].

• a) Research should advance systems’ capabilities to react to learners’ abilities and difficulties, and
provide systematic feedback based on innovative ways of interpreting the user’s responses [⋯].

• d): innovative tools encouraging nonlinear, non-standard thinking and problem-solving, as well as
the exploration and generation of new knowledge, ideas and concepts, or new associations between
existing ideas or concepts.

• For all target outcomes, projects should include a scientifically sound evaluation component.

Moreover, DEDUCATION also fits to related issues in the Challenge 8, in particular c) targeting, in particular;
SMEs): enable faster, situated, just-in-time up-/reskilling, and lower the costs/efforts of developing and
maintaining quality instructional material to be used in continuing education and training processes. and
will help SMEs to adopt and sustain effective learning attitudes.

Last but not least, DEDUCATION also addresses several global themes of the FP7 call in a local context:


• Objective ICT-2011.3.4 Computing Systems; a) Parallel and Concurrent Computing

• Objective FI.ICT-2011.1.7 Technology foundation: Future Internet Core Platform

Table 1 (targets) and Table 2 (expected impact) briefly summarize the relevance of DEDUCATION to the
topics addressed by the call. It will be discussed in more details in the following paragraphs.

Success criteria. This section summarizes DEDUCATION’s intended goals, with measurable outputs
broken down to a level of granularity that they can be related to the project objectives from Table 1 (targets)
and Table 2. The following Table 3 also relates those measurable outputs to the work packages as introduced
in detail in Section 1.3. The foundation for the technical activities in form of functional, as well as non-
functional requirements are set by OBJ.1–2. These foundations are then validated in the following delivery
of prototypes within each activity that implement the corresponding enforcement mechanisms OBJ.3–5.
The readiness is measured by pre-integration tests of the enforcement mechanisms, and by non-functional
b1) Supporting students to understand and construct their personal conceptual knowledge and meaning of scientific, technological and/or mathematical subjects . . .

The DEDU-framework allows the student to explore solutions by supporting incremental solution checking and elaboration of mathematical derivation and modelling activities (OBJ.1).

b1) Technological solutions should take the learners through the complexity of a subject, activating and feeding curiosity and reasoning […]

The DEDU-Web framework provides high-level support for textual and graphical representation and interaction (OBJ.3). The PRTEs developed offer presentation m Teaching methodologies adapted to a problem domain, a particular emphasis is put on systems offering a a visual view on reasoning and deduction (OBJ.4).

a) Research should advance systems’ capabilities to react to learners’ abilities and difficulties, and provide systematic feedback based on innovative ways of interpreting the user’s responses […]

The DEDU-framework has infrastructure for user-guidance, faulty proof-attempt analysis and student assessment (OBJ.1); the PRTEs are adapted to a problem domain and the addressed target group (OBJ.4).

d): innovative tools encouraging nonlinear, non-standard thinking and problem-solving, as well as the exploration and generation of new knowledge, ideas and concepts, or new associations between existing ideas or concepts.

The DEDU-framework provides infrastructure for collaborative learning in distributed environment, support for versioning and merging of distributed formal content (OBJ.2).

For all target outcomes, projects should include a scientifically sound evaluation component.

We plan an empirical evaluation based on carefully chosen reference examples in schools and universities (OBJ.5).

Table 1: DEDUCATION objectives vs. targets of the call.

<table>
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<tr>
<th>FP7-ICT-2011-8.1 Call</th>
<th>DEDUCATION Objectives</th>
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<tr>
<td>Significantly higher level of effective, personalised, ICT-based tutoring, leading to its widespread penetration in schools and at home.</td>
<td>The DEDU-Web framework is easily deployable, and as a cloud service a single installation can reach a huge number of users (OBJ.3).</td>
</tr>
<tr>
<td>Higher level of engagement of youngsters in science, technology and maths, through novel educational software, and opening up opportunities to access and use of laboratory equipments and virtual experiments.</td>
<td>Guided proofs as offered by DEDUCATION are the mathematical equivalent of experimentation (OBJ.1, OBJ.4). Visual representations and innovative frontend technology (web-based, app-based) will reach out to first adapters of novel consumer technology (OBJ.3).</td>
</tr>
<tr>
<td>Faster, more timely and more cost-effective up/re-skilling through learning technologies and their sustained adoption by SMEs.</td>
<td>One partner is using the infrastructure for company teaching efforts in a security domains.</td>
</tr>
<tr>
<td>Emergence of new learning models, including models invoking creativity</td>
<td>Teaching and learning is based on explicit semantic knowledge (theories).</td>
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Table 2: Relevance of DEDUCATION to the call: expected impact.
validations by (small) field studies in schools and universities. Results mirroring the project’s success are continuously disseminated in suitable scientific circles and an industrial exploitation is pursued (OBJ.6).

<table>
<thead>
<tr>
<th>Objective</th>
<th>Criteria Description</th>
<th>WPs</th>
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<tr>
<td>OBJ.1</td>
<td>Implementation of the EDUCATION’s DEDU-Framework, its integration in the DEDU-Web framework. Validation by use in at least 5 PRTEs, where one is an industrial training scenario.</td>
<td>WP1, 2, 3, 4</td>
</tr>
<tr>
<td>OBJ.2</td>
<td>Implementation of the EDUCATION’s DEDU-Framework, and its validation by use in at least 2 PRTEs using collaborative content development</td>
<td>WP1, 2, 3, 4</td>
</tr>
<tr>
<td>OBJ.3</td>
<td>Implementation of the EDUCATION’s DEDU-Web framework and its validation by use in at least 2 web-based PRTEs.</td>
<td>WP2, 3, 4</td>
</tr>
<tr>
<td>OBJ.4</td>
<td>Design and implementation of at least 5 PRTEs, where one is an industrial training scenario. The enforcement is validated with functional tests and non-functional validations of OBJ.5.</td>
<td>WP3, 4</td>
</tr>
<tr>
<td>OBJ.5</td>
<td>Design and execution of empirical studies of chosen PRTEs.</td>
<td>WP5</td>
</tr>
<tr>
<td>OBJ.6</td>
<td>Scientific dissemination and industrial exploitation of results. This includes publication of the implementations of WP1,2 and some PRTEs (WP3,4), scientific publications and implementation tutorials (in the tradition of Isabelle Developer Tutorials), and an reference server installation to be maintained more than 3 years after project end.</td>
<td>WP 6</td>
</tr>
</tbody>
</table>

Table 3: Success criteria

1.2 Progress beyond the state-of-the-art

The recent report *PISA 2012 Mathematics Framework* [56], identifies “mathematical literacy” with the following core competences:

1. Communication: “…perceiving the existence of some challenge and recognizing and understanding a problem situation . . .”.
2. Mathematising: “…transforming a problem defined in the real world to a strictly mathematical form . . .”.
3. Representation: “…selecting, interpreting, translating between, and using a variety of representations to capture a situation, interact with a problem, or to present one’s work . . .”.
4. Reasoning and argument: “…logically rooted thought processes that explore and link problem elements so as to make inferences from them, check a justification that is given, or provide a justification of statements or solutions to problems . . .”.
5. Devising strategies for solving problems: “…critical control processes that guide an individual to effectively recognise, formulate and solve problems . . .”.
6. Using symbolic, formal and technical language and operations: “…understanding, interpreting, manipulating, and making use of symbolic expressions within a mathematical context . . .”.
7. Using mathematical tools: “…knowing about and being able to make use of various tools that may assist mathematical activity, and knowing about the limitations of such tools . . .”

The adequacy of software for mathematics education can be thus measured by how well it supports the development of these competences. The claim of EDUCATION is that computer-based theorem proving (TP) is a key technology to support developing most of the above competences by using a formal semantic model as the basis of the domain that is addressed by a particular PRTE: the activities that a user performs can be mirrored in the model and their logical correctness can be judged (and in case of errors suitable explanations be given) and the software may even suggest how to proceed in these activities.
This does not imply that the student has to be necessarily exposed to all the formal details of the underlying semantic model and the corresponding logical inferences; the PRTE may provide adequate views to the domain/problem at hand using various forms of presentation and level of abstraction. Also the application of TP-based software does not mean that math teachers become obsolete, rather their role shifts to that of mentors and supervisors.

However, in view of the competences required for mathematical literacy, the state of the art in mathematics education software is characterized by a set of unconnected, partial solutions that do not take into account in a comprehensive way the possibilities of modern computer mathematics on one side (the added educational value that can be provided by TP-systems with respect to the above goals) and of modern system technologies on the other side (the possibility to provide the required TP-functionality on dedicated server farms as a service that can be accessed via the internet remotely by different educational tools). In the remainder of this section, we will survey various technological facets of mathematics education software related to the goals of the project.

**Mathematical Software Systems.** There exist a number of computer algebra systems such as Mathematica or Maple as well as special systems for geometry based on algebraic methods [24, 26, 27, 84]). These systems work in a black-box fashion: they deliver results but do not provide a way to understand its computation and no justification for its correctness. This considerably limits their educational value. In contrast, DEDUCATION focuses on white-box computations whose steps are exhibited and justified by logical reasoning which allows the user to understand how the result was derived and raises her awareness for formal justification. Furthermore, it is possible to combine proof-search techniques and explanatory techniques on the basis of formal proofs, let it be in form of symbolic execution combined with next-step-guidances [44] or automated proof attempts as the basis for high-level hints with increasing explicitness down to next-step-guidance as well as for qualitative proof step analysis which also allows to include “buggy rules” encompassing common errors in reasoning [4, 31, 32].

**TP-Functionality in the Web.** There have been numerous attempts to integrate interactive theorem provers into web based environments. One example is the HELM project (http://helm.cs.unibo.it/) from Bologna, which exposes formal content produced by theorem provers on the web. Its general focus is on interactive browsing and querying of static libraries that have been checked by the prover; editing and producing new content on the web is not supported. MathWiki (http://www.fnds.cs.ru.nl/fndswiki/Research/MathWiki) is an ongoing effort from Nijmegen that aims to get more interaction into the web view of classic provers (Coq, Isabelle, Mizar). Classic Wiki technology combined with formal proof checking in the background (the server side) is intended to facilitate large-scale distributed development of formal mathematical theories. The EU project e-math (http://e-math.imped.fi/), funded till 2013, aims to build a web-based environment for learning mathematics; it provides an experimental integration of the TP system PVS [59] to support a rather coarse-grained check of solutions.

These projects already point in the same direction as DEDUCATION, but we would like to go much farther by wrapping up theorem provers more rigorously, to make them the foundational engine for teaching material, but without exposing the users to the classic proof engine that goes back to LCF from the 1970s. Furthermore, we will address topics of general mathematics, not only logic itself in the narrow sense. Thus the formal prover technology becomes a means to teach mathematics with full foundations, rather than an end in itself. DEDUCATION will combine, among others, the e-math-project like PRTEs with the fine-grained, asynchronous, cloud-ready technology and the logically safe, highly trustworthy ITPs Isabelle [81] and Coq [28].

**Isabelle PIDE Framework.** At present, the PIDE framework of the ITP Isabelle [81] offers a programmable interface (API) for manipulations on a formal document. In the ongoing project Paral-ITP
(http://paral-itp.lri.fr/), this API is generalized to provide a common generic interface to Isabelle and Coq. EDUCATION will apply this technology to mathematics education, in particular enabling pupils to do their own — typically non-linear — calculations and proof attempts. The technology is particularly important for strong server technologies implied by web-based PRTEs.

The PIDE framework of Isabelle also offers an API for manipulations on a formal document. This document can contain definitions, hypertext, technical information and proof attempts, which are checked in parallel (see above), and is applicable to Coq [28] (see ongoing project Paral-ITP). However, the relation between a system kernel and a user client is currently strictly limited to a one-to-one correspondence, not exploiting the inherent parallelism of the inference kernel. EDUCATION will add a multi-client access to the document model (i.e. user sessions), and infrastructure to manage a truly distributed document model with access control and (semantically checked) merges of different document versions.

Semantic-based Visual PRTEs. GeoGebra (http://www.geogebra.org) is a free dynamic geometry software that also includes support for algebra, tables, graphing, statistics and calculus. AgentGeom is an artificial tutorial system which is designed to help students in geometry. Neither GeoGebra nor AgentGeom applies TP-technology. Baghera is a distance learning environment providing individualised support for problem solving in the domain of geometry proofs. The ANR project Galapagos (http://galapagos.gforge.inria.fr/) was dedicated to formalization of geometry and computational geometry with applications in education.

The novelty of our approach consists in using a general purpose proof assistant to provide the foundations of the system. The framework will contain the definition of our geometry models using Coq and Isabelle. We will reuse the common file format for dynamic geometric software developed in the European Intergeo project (2007-2010) and define an extension of the I2g common file format to represent statements. EDUCATION will allow to extend the work of Galapagos to build usable systems and validate their use.

Semantic-based Textual PRTEs. Various mathematics-oriented PRTEs have been discussed in the context of “TP-Functionality in the Web” above. In the world of programming, Invariant-based programming (IBP) is a “formal approach to practical programming” that has already been successfully used as a pedagogical device [7, 9]; this is currently supported by the Socos environment [33] (see http://imped.abo.fi/socos), which uses the PVS system [59] as a verification back-end. Within EDUCATION, the Socos environment will be extended into a zero-defect programming environment based on the DEDU-framework, allowing invariant-based programs to be continuously checked by a cloud of dedicated servers. Additionally, we plan to augment the Socos environment with a verifying compiler which automatically constructs for each compiled invariant-based program a correctness proof based on the verification conditions.

The already mentioned project e-math focuses on building web tools based on the logic method of Structured derivations (SD) [8] with electronic course material to disseminate the method among teachers. We will connect the web tools to the DEDU-framework, allowing student solutions to be checked on request by a cloud of dedicated servers. All errors found in the proposed solution will immediately be reported back to the student (and possibly, to the teacher). The main challenge here is ensuring that the feedback is timely and presented in a comprehensible format, so that interaction with the system in an explorative way continuously motivates the student to improve his or her reasoning skills.

Assessment of Mathematical Solutions. The current practice in the computer-supported assessment of mathematical exercises (e.g., in the learning management system Moodle, http://www.moodle.org) is to provide a choice of answers from which the student may select the right one, or to use a question pattern that is instantiated with random values and whose numerical result is calculated by the symbolic evaluation of a formula. A more general approach is applied by the STACK system (http://www.stack.bham.ac.uk), where
a computer algebra kernel checks the correctness of a (symbolic) answer.

In DEDUCATION, by application of TP more innovative forms of assessments become possible: a question may not only demand a final answer but a derivation whose individual steps may be automatically checked, thus not only the solution but its derivation is assessed; by restricting the knowledge base, only inference steps on the currently considered level of abstraction may be accepted; by precomputing inference trees the “distance” of an intermediate solution to the final result may be shown; in a given situation hints on applicable next steps may be provided.

1.3 S/T methodology and associated work plan

1.3.1 Overall strategy of the work plan

DEDUCATION is a 36 month project that can be subdivided in five main parts, corresponding to work packages WP1–WP5; the project comprises also one other work package, WP 6, which is devoted to project management and dissemination.

The dependencies between the technical work packages — reflecting to a certain extent the dependencies of the components described in Figure 2 — are depicted in Figure 3.

Figure 3: Dependencies between the technical work packages

WP 1 will culminate in the definition and implementation of the DEDUCATION Framework; the delivery will be organised as a series of different versions representing different degrees of extensions of the framework. Note that core implementations of PRTEs (just modeling core theories, proofs, the symbolic computations for hints etc.) can be implemented without the framework (providing sessions, access control and assessment) directly in the underlying ITP systems.

WP 2 will result in the DEDU-Web framework, allowing development and deployment of DEDUCATION-PRTEs as web applications. The framework will provide, on the server side, an abstract and uniform means to access PRTE resources, and on the client side, a collection of interactive display and editing components which can be utilised to conveniently build a PRTE web application.

WP 3 and 4 will provide series of PRTEs as instances of the DEDU-framework; this also requires the
adaptation of existing context such as geometrical libraries (e.g., provided by UC) and mathematical textbooks (e.g., provided by AAU) for larger PRTE demo scenarios. As a common denominator, WP 3 PRTEs are oriented towards visual/graphical presentations, while WP 4 PRTEs present mathematical content in some textual form for investigation and manipulation. For both types of presentations, domain-specific automatic feedback and next-step-guidance, proof tutoring, and student assessment will be developed — in fact, the differences in these domains wrt. presentation and user-guidance techniques motivate the separation of textual and visual PRTEs. WP 4 also includes a learning environment from the industrial partner for secure programming.

**Note** that both WP 3 and WP 4 depend on WP 1 and 2, but since important preparation work like the development of the underlying formal theories and tactics can be done directly in Isabelle and Coq, tasks of these WPs can be started before delivery of the first version of the DEDU-Framework (Deliverables D1.1-4).

In WP5 we will perform a series of evaluations of chosen PRTEs in realistic (school and university) scenarios; its purpose is the validation of concepts, techniques and PRTEs resulting from the other work packages, providing most fruitful feedback for their development.

Hence, at all stages of DEDUCATION, the design decisions will be validated by their application to complex security services: this is by itself a challenging feature of this proposal.

### 1.3.2 Timing of the different WPs and their components

A GANTT chart depicting the scheduling of the work packages is given in Figure 4: it depicts the timelines of the single work packages and their tasks. Note that the dependencies between the tasks and deliverables is not shown in this chart, these dependencies are illustrated in a PERT chart (see subsubsection 1.3.4 for details).

### 1.3.3 Detailed work description broken down into work packages

**Table 1.3a: Work package list**

<table>
<thead>
<tr>
<th>Work package No.</th>
<th>Work package title</th>
<th>Type of activity</th>
<th>Lead partic.</th>
<th>Person-months</th>
<th>Start month</th>
<th>End month</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP 1</td>
<td>DEDU-Framework</td>
<td>RTD</td>
<td>UPSud</td>
<td>92</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>WP 2</td>
<td>DEDU-Web Framework</td>
<td>RTD</td>
<td>DFKI</td>
<td>53</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>WP 3</td>
<td>Visual PRTEs</td>
<td>RTD</td>
<td>UdS</td>
<td>157</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>WP 4</td>
<td>Textual PRTEs</td>
<td>RTD</td>
<td>JKU</td>
<td>185</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>WP 5</td>
<td>Case Studies and Empirical Evaluation</td>
<td>RTD</td>
<td>AAU</td>
<td>77</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>WP 6</td>
<td>Project Management and Dissemination</td>
<td>MGT</td>
<td>UPSud</td>
<td>34</td>
<td>1</td>
<td>36</td>
</tr>
</tbody>
</table>
Figure 4: GANTT Chart of the EDUCATION Project
Table 1.3b: Deliverables list

<table>
<thead>
<tr>
<th>Del. no.</th>
<th>Deliverable name</th>
<th>WP no.</th>
<th>Nature</th>
<th>Dissemination level</th>
<th>Delivery date (PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1.1</td>
<td>Initial Design and Impl. of core DEDU-Framework.</td>
<td>1</td>
<td>P</td>
<td>PU</td>
<td>6</td>
</tr>
<tr>
<td>D1.2</td>
<td>First version of Reference Manual and First Developer Tutorial Material</td>
<td>1</td>
<td>R</td>
<td>PU</td>
<td>12</td>
</tr>
<tr>
<td>D1.3</td>
<td>Design and Impl. of DEDU-Framework with Collab. Document</td>
<td>1</td>
<td>P</td>
<td>PU</td>
<td>18</td>
</tr>
<tr>
<td>D1.4</td>
<td>Design and Impl. of DEDU-Framework with Access Control</td>
<td>1</td>
<td>P</td>
<td>PU</td>
<td>24</td>
</tr>
<tr>
<td>D1.5</td>
<td>Second version of Ref. Manual and Second Developer Tutorial Material</td>
<td>1</td>
<td>R</td>
<td>PU</td>
<td>24</td>
</tr>
<tr>
<td>D1.6</td>
<td>Final Design and Implementation of the DEDU-Framework</td>
<td>1</td>
<td>P</td>
<td>PU</td>
<td>36</td>
</tr>
<tr>
<td>D2.1</td>
<td>Extension of the core DEDU-Framework to a REST-based web API.</td>
<td>2</td>
<td>R</td>
<td>PU</td>
<td>12</td>
</tr>
<tr>
<td>D2.2</td>
<td>Provision of a set of client-side editing and display components, first prototype of web interface.</td>
<td>2</td>
<td>P</td>
<td>PU</td>
<td>18</td>
</tr>
<tr>
<td>D2.3</td>
<td>Fully functional web interface.</td>
<td>2</td>
<td>P</td>
<td>PU</td>
<td>30</td>
</tr>
<tr>
<td>D2.4</td>
<td>Final version of web interface, possibly supplemented by customised frontends (“apps”) for particular devices.</td>
<td>2</td>
<td>P</td>
<td>PU</td>
<td>36</td>
</tr>
<tr>
<td>D3.1</td>
<td>Report on the specification of the DEDU-specific functionality of the visual PLEs and the corresponding requirements to the DEDU-Framework.</td>
<td>3</td>
<td>R</td>
<td>PU</td>
<td>6</td>
</tr>
<tr>
<td>D3.2</td>
<td>Report on the definition of a language for describing conjectures built upon the current i2g standard.</td>
<td>3</td>
<td>R</td>
<td>PU</td>
<td>6</td>
</tr>
<tr>
<td>D3.3</td>
<td>Report on a first prototype of visual PLE for geometry</td>
<td>3</td>
<td>P</td>
<td>PU</td>
<td>18</td>
</tr>
<tr>
<td>D3.4</td>
<td>Report on the foundational work about geometric constructions</td>
<td>3</td>
<td>R</td>
<td>PU</td>
<td>30</td>
</tr>
<tr>
<td>D3.5</td>
<td>Report on the final visual PLE for geometry integrated in the DEDU Framework</td>
<td>3</td>
<td>P</td>
<td>PU</td>
<td>36</td>
</tr>
<tr>
<td>D4.1</td>
<td>Report on design and requirements.</td>
<td>4</td>
<td>R</td>
<td>PU</td>
<td>6</td>
</tr>
<tr>
<td>D4.2</td>
<td>Report on first skeleton prototypes.</td>
<td>4</td>
<td>R</td>
<td>PU</td>
<td>18</td>
</tr>
<tr>
<td>D4.3</td>
<td>Report on intermediate prototypes.</td>
<td>4</td>
<td>R</td>
<td>PU</td>
<td>24</td>
</tr>
<tr>
<td>D4.4</td>
<td>Report on final software versions.</td>
<td>4</td>
<td>R</td>
<td>PU</td>
<td>30</td>
</tr>
<tr>
<td>D5.4</td>
<td>Description of PRTEs to be evaluated, use case scenarios and participating pilot sites.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>12</td>
</tr>
<tr>
<td>D5.2</td>
<td>Experimentation methodology and plan for the first phase field studies.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>12</td>
</tr>
<tr>
<td>D5.3</td>
<td>Description of an automatic data collection tool.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>18</td>
</tr>
<tr>
<td>D5.4</td>
<td>Presentation of the educational material and summary of experiences from first phase field studies.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>24</td>
</tr>
<tr>
<td>D5.5</td>
<td>Updated experimentation plan for second phase field studies.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>30</td>
</tr>
<tr>
<td>D5.6</td>
<td>Presentation of the revised educational material and summary of experiences from second phase field studies.</td>
<td>5</td>
<td>R</td>
<td>PU</td>
<td>36</td>
</tr>
<tr>
<td>D6.1</td>
<td>Project Quality Handbook</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>3</td>
</tr>
<tr>
<td>D6.2</td>
<td>First Progress Report</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>12</td>
</tr>
<tr>
<td>D6.3</td>
<td>Initial dissemination and exploitation plan</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>12</td>
</tr>
<tr>
<td>D6.4</td>
<td>Second Progress Report</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>24</td>
</tr>
<tr>
<td>D6.5</td>
<td>Second dissemination and exploitation plan</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>24</td>
</tr>
<tr>
<td>D6.6</td>
<td>Final Project Report</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>36</td>
</tr>
<tr>
<td>D6.7</td>
<td>Final dissemination and exploitation plan</td>
<td>6</td>
<td>R</td>
<td>CO</td>
<td>36</td>
</tr>
</tbody>
</table>
Table 1.3c: List of milestones

The work in DEDUCATION is structured by seven milestones, which coincide with kickoff and final meetings as well as the biannual project meetings. Since the meetings are the main face-to-face interaction points in the project, the milestones (essentially the release of different versions of deliverables) are actually put in sync with these events, where they can be discussed in detail.

<table>
<thead>
<tr>
<th>#</th>
<th>Event</th>
<th>Mo.</th>
<th>Description</th>
<th>Means of Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>Kickoff</td>
<td>1</td>
<td>Initial (Organizational) Project Infrastructure</td>
<td>Inspection</td>
</tr>
<tr>
<td>M1</td>
<td>T6</td>
<td>6</td>
<td>DEDU-Framework I, Embeddings in Coq and Isabelle I</td>
<td>Inspection, Demo, Test</td>
</tr>
<tr>
<td>M2</td>
<td>T12</td>
<td>12</td>
<td>First Project Review</td>
<td>Inspection, Demo, Test</td>
</tr>
<tr>
<td>M3</td>
<td>T18</td>
<td>18</td>
<td>PRTE-Versions I, Demonstrator PRTE, Web-Framework I, Embeddings in Coq and Isabelle II</td>
<td>Inspection, Demo, Test</td>
</tr>
<tr>
<td>M5</td>
<td>T30</td>
<td>30</td>
<td>PRTE-Versions III, Evaluations I</td>
<td>Inspection, Demo, Test</td>
</tr>
<tr>
<td>M6</td>
<td>Final</td>
<td>36</td>
<td>Final Review, Evaluations II</td>
<td>Demos, Inspection</td>
</tr>
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</table>
Table 1.3d: Work package descriptions

<table>
<thead>
<tr>
<th>Work Package</th>
<th>Description</th>
<th>Objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: DEDU-Framework</td>
<td></td>
<td>1. Implementation of the DEDU-Framework. This proceeds by providing a “Server-Version” of the existing PIDE Framework, which allows to dynamically create multiple sessions, which provide a “view” on the underlying asynchronous proof and document processing related to the session.</td>
</tr>
<tr>
<td>2: UPSud</td>
<td></td>
<td>2. Implement an infrastructure for collaborative working, i.e. a version management including merge on different versions of documents. Conflicts were handled by specific methods to the document type and means to guide user-interaction for local conflict resolution.</td>
</tr>
<tr>
<td>3: DFKI</td>
<td></td>
<td>3. Include a problem-oriented adapted access control model for formal documents.</td>
</tr>
<tr>
<td>4: SAP</td>
<td></td>
<td>4. Include an infrastructure for teaching assessment (measuring solutions, their quality, and the degree of help used in providing them, i.e. next-step-guidance, hinting, error-feedback). An export to an assessment infrastructure such as MOODLE is added.</td>
</tr>
<tr>
<td>5: JKU</td>
<td></td>
<td>5. Project-intern and extern dissemination of the DEDU-Framework.</td>
</tr>
<tr>
<td>6: UC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7: AAU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8: FMUBg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Description of Work:** WP 1 is concerned with the development and dissemination of the projects core-component. The development is organized as a cyclic development process, where conception and implementation are interleaved and structured into half-year release cycles. The package identifies the tasks:

**T1.1. Conception** of the DEDU-Framework. This task involves the creation of (partially formal) design and architecture models, comprising in particular a concrete design for the access control and interfaces to specific merge methods as well as assessment functions. The core version of this task will be described in a report which describes the design and technical architecture of the DEDU-Framework (D1.1), which will be extended in a number of internal releases. (D1.3, D1.4, and D1.6)

**T1.2. Implementation** of the DEDU-Framework. Starting from an early version comprising multi-sessions setup on a server infrastructure (D1.1), the system is gradually extended by version management (D1.3), access control (D1.4), and an infrastructure to extract session-related, empirical data from the very fine-grained increments on the document model. This task culminates in Deliverable D1.6.

**T1.3. Integration** of features requested by other partners of the consortium, in particular the DEDU-Web framework (essentially a web-interface to a DEDU-Framework session thread), the assessment and a reporting infrastructure, and other (minor) features specific to PRTEs (on mutual agreement). (D1.3,D1.4,D1.6).

**T1.4. Dissemination** of the results and provision of services. This includes reference manuals (D1.2,D1.5), the organization of developer tutorials (in the tradition of Isabelle Developer Tutorials, (D1.2,D1.5)), and a setup of a server infrastructure (part of D1.1).

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Description</th>
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<tbody>
<tr>
<td>D1.1: (Month 6)</td>
<td>Initial Design and Impl. of core DEDU-Framework.</td>
</tr>
<tr>
<td>D1.2: (Month 12)</td>
<td>First version of Reference Manual and First Developer Tutorial Material</td>
</tr>
<tr>
<td>D1.3: (Month 18)</td>
<td>Design and Impl. of DEDU-Framework with Collab. Document</td>
</tr>
<tr>
<td>D1.4: (Month 24)</td>
<td>Design and Impl. of DEDU-Framework with Access Control</td>
</tr>
<tr>
<td>D1.5: (Month 24)</td>
<td>Second version of Ref. Manual and Second Developer Tutorial Material</td>
</tr>
<tr>
<td>D1.6: (Month 36)</td>
<td>Final Design and Implementation of the DEDU-Framework</td>
</tr>
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## Work Package 2: DEDU-Web Framework

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### Objectives:

1. Design and implementation of a server-side framework which allows web-based access to the learning material as a thin layer over the PIDE document model from WP 1.
2. Design and implementation of a set of interactive components on the client side, which allow intuitive display and exploration as well as WYSIWYG editing of the material.
3. Together, this results in a web-frontend usable out-of-the-box with recent web browsers, and deployable by standard means on the server side.
4. We further will investigate whether to provide additional customized front-ends such as apps for tablets or other mobile devices.

### Description of Work:

In this work package, we develop an extension of the DEDU framework for web-based interaction. As a starting point, we use the Lift framework [25], a state-of-the-art web framework implemented in Scala, which makes a smooth integration with the Common Scala API from WP 1. It offers good abstractions over features such as Ajax and Comet used in interactive web applications. However, on project start we will investigate if a timelier framework is available.

**T2.1 Server:** On the server side, we need a lightweight infrastructure layer on top of the Common Scala API which provides a REST-ful interface to the learning material, turning nodes in the development graph into (editable) URIs (D2.1).

**T2.2 Clients:** On the client side, we need a set of interactive display and editing components which allow the intuitive manipulation of mathematical formulae (D2.2, D2.3). The core of these will be a WYSIWYG editing component, and a component to display mathematical text, but there may be others, e.g. for geometry or to navigate the session graph.

**T2.3 Integration:** The integration of T2.1 and T2.2 will provide a standard web interface which works on all recent HTML browsers, leveraging recent technologies such as HTML5, CSS3 and web sockets (D2.2–D2.4). We will not provide backwards compatibility to legacy browser technology.

**T2.4 Mobile frontends:** We will further investigate whether customised frontends (“apps”) for mobile devices such as tablets or smartphones offer a return on the investment of implementation effort (D2.4).

<table>
<thead>
<tr>
<th></th>
<th>(Month 12)</th>
<th>Extension of the core DEDU-Framework to a REST-based web API.</th>
<th>M1</th>
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<td>D2.2: (Month 18)</td>
<td>Provision of a set of client-side editing and display components, first prototype of web interface.</td>
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<td>D2.3: (Month 30)</td>
<td>Fully functional web interface.</td>
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<td>D2.4: (Month 36)</td>
<td>Final version of web interface, possibly supplemented by customised frontends (“apps”) for particular devices.</td>
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**Work Package 3: Visual PRTEs**

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**Objectives:**
The objective of this WP is to provide a family of PRTE/PLE which promote a predominantly visual access to the problem domain (geometry, automata). However, some PRTE scenarios may allow multiple views on a problem solution, e.g. a visual presentation of Euclidean proofs as well as a logical proof for didactic purposes.

1. Integration of DGSs, GATP and ITP around a PLE for geometry construction problems.

**Description of Work:** The main objective of this work package is to provide a visual PLE for interactive formal proof in geometry. We will integrate GeoGebra and JSXGraph in the DEDU Framework and DEDU-Web Framework. This will require first to:

1. Develop a set of tools for automated solving of geometric construction problems and verification of solutions.
2. Definition of a language for describing conjectures and proofs.
3. Provide a repository of geometry problems with visualisation within a web environment.

The next-step-guidance functionality will be built in collaboration with WP2 and WP4. The integration of GeoGebra/JSXGraph as a PLE will be based on the API built in collaboration with WP1, WP2, and WP4.

**T3.1. Conception:** Specify the DEDU-specific functionality of the PLE and the corresponding requirements to the DEDU framework. Define a language for describing conjectures built upon the current i2g standard (D3.1, D3.2).

**T3.2. Foundations:** Foundational work needed for the project which does not need the DEDU framework. Develop a formalization of geometric constructions, a certified geometric construction solver, and a tool for validation of geometric constructions (D3.4).

**T3.3. Implementation:** Implementation of prototype of PLE for geometry based on the foundational work for starting empiric evaluation. Integration of a web repository of geometric problems (D3.3, D3.5).

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<tbody>
<tr>
<td>D3.1: (Month 6) Report on the specification of the DEDU-specific functionality of the visual PLEs and the corresponding requirements to the DEDU-Framework.</td>
<td>⇝M1</td>
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<tr>
<td>D3.2: (Month 6) Report on the definition of a language for describing conjectures built upon the current i2g standard.</td>
<td>⇝M1</td>
<td></td>
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<tr>
<td>D3.3: (Month 18) Report on a first prototype of visual PLE for geometry</td>
<td>⇝M3</td>
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<tr>
<td>D3.4: (Month 30) Report on the foundational work about geometric constructions</td>
<td>⇝M5</td>
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<tr>
<td>D3.5: (Month 36) Report on the final visual PLE for geometry integrated in the DEDU Framework</td>
<td>⇝M6</td>
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</tbody>
</table>
Objectives: The objective of this WP is to provide a family of PRTEs which promote a predominantly
textual access to the problem domain (programming, interactive math textbooks) providing:
- Logical embeddings and deductive support in Isabelle or Coq
- Tactical support for test-case-derivations for critical programming applications
- Tactical Support for verification of elementary programming applications
- Mathematical textbook support in web-scenarios, automatic checking of student solutions
- Mathematical content authoring (an extension of Isabelle/jEdit)
- Interpretation and next-step-guidance functionality

Description of Work:
This WP aggregates R&D on the following PRTEs: 1. Learning Environment for Mathematics with Automatic Feedback (Structured Derivations). 2. Web-based Proof Tutoring Support. 3. Mathematics with next-step-guidance (ISAC). 4. Zero-Defect Programming Environment (Socos). 5. Learning Environment for Secure Programming. All PRTEs use text or formulas for interaction with ATP/ITP; the work package comprises work to be done in parallel as well as joint work (e.g. the requirements elicitation of the DEDUCATION framework API). The PRTEs have different front-ends (e.g., Web-based, based on Isabelle/jEdit). All front-ends use the DEDUCATION core framework.

Work on each PRTE proceeds iteratively, with a specification of the functionality and the requirements to the DEDU Framework respectively DEDU-Web Framework (D4.1), followed by the development of a skeleton prototype as the basis for further refinement and a starting point for the case studies and empirical evaluation (D4.2), intermediate versions for detailed mid-phase evaluation (D4.3), and a final version for evaluation and exploitation (D4.4). For all PRTEs in common, the following tasks have to be performed (the specific details may vary for each PRTE):

T4.1. Design and Requirements: Design the DEDU-specific functionality of the PRTE and specify the corresponding requirements to the DEDU framework; these requirements will be specified in deliverable D4.1 which serves as the interface to WP1 (see the corresponding deliverable D1.1).
T4.2. Core Implementation: Develop a first skeleton prototype with core functionality for starting tests and content development for case studies and empirical evaluation. This prototype implements (on the basis of deliverables D1.2 and D2.1) the technical interface to the DEDU (Web)-Framework and demonstrates its operability (and thus provides the basis for D5.4 in WP5); its architecture and functionality is described in deliverable D4.2.
T4.3. Functionality and Content: Develop an intermediate prototype with the essential functionality as a basis for mid-phase evaluation. This prototype enriches (on the basis of deliverables D1.3, D1.4, D2.2 and D2.3) the previously presented skeleton with the functionality required for actual content development and first assessments (as the basis of D5.5); the results are described in deliverable D4.3.
T4.4. Revision: Revise the software into its final version for further evaluation. This version represents the version of the software that provides the basis for corresponding assessments (as the basis of D5.6); the results are described in deliverable D4.4.
T4.5. Packaging: Polish and package the software for dissemination and provide appropriate end-user documentation. This task turns the results of the WP4 into a distributable software package; the software package and the documentation represent deliverable D4.5.

D4.1: (Month 6) Report on design and requirements. ~M1
D4.2: (Month 18) Report on first skeleton prototypes. ~M3
D4.3: (Month 24) Report on intermediate prototypes. ~M4
D4.4: (Month 30) Report on final software versions. ~M5
D4.5: (Month 36) Software packages and end-user documentation. ~M6
Work Package 5: Case Studies and Empirical Evaluation

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Objectives:
All PRTEs included in DEDUCATION will be empirically evaluated to some extent when used in educational settings. In addition, a selection of the PRTEs will be thoroughly evaluated through empirical studies. The objectives of this WP are to plan, design and implement a systematic evaluation of a set of PRTEs in order to provide feedback based on empirical experiences. This kind of feedback is important both to practitioners, who are interested in using the PRTEs in their own context and to developers, who benefit from reality checks with regard to how the PRTE works in authentic settings (what works as is, what needs to be changed, what needs to be added, etc). The work in WP5 can be seen as a collection of formative studies aiming at evaluating and thereby improving the way in which the evaluated PRTEs are used in an educational or business context.

Description of Work:
The empirical evaluation will be conducted based on a developmental research framework [62, 75]. In educational settings the emphasis of this type of research is usually on developing a new instructional product or program through an iterative process of R&D. The overall goal in the DEDUCATION context is to provide suggestions for how the quality of a PRTE can be optimized, by testing design solutions in practice. The main result is knowledge that is usable by practitioners. As the PRTEs are computer based, we are able to collect various types of valuable data about how users use the PRTE. Hence, a customized and automatic data collection tool will be developed in order to make it easy to collect interesting data. In particular, the tool needs to be able to address the evaluation criteria developed in this WP.

T5.1. Select a set of PRTEs to be rigorously evaluated at a set of pilot sites (high school, university, business) (D5.1).

T5.2. Develop a set of formal assessment criteria to be used in the evaluation based on previous work and relevant literature (D5.2).

T5.3. For each selected PRTE, develop the educational material and design an empirical study including analysis methods and data collection tools, which makes it possible to evaluate the PRTE with regard to the criteria developed in T5.2 (D5.3).

T5.4. Conduct a set of empirical studies in the chosen contexts (T5.1) according to the developed study plan in order to provide feedback on the suitability and performance of the PRTE in the given context. At the beginning of each study baseline data will be collected. This includes, e.g., demographic data, grades and additional data from customized start tests specifically developed for DEDUCATION purposes addressing, e.g., students’ mathematical knowledge level and computer skills. (D5.4, D5.5).

T5.5. Disseminate the educational material and the experiences from the case studies, in order to create feedback loop from practitioners to the developers of the PRTEs to facilitate updates and modifications. (D5.4, D5.6).

D5.1: (Month 12) Description of PRTEs to be evaluated, use case scenarios and participating pilot sites. ~M2
D5.2: (Month 12) Experimentation methodology and plan for the first phase field studies. ~M2
D5.3: (Month 18) Description of an automatic data collection tool. ~M3
D5.4: (Month 24) Presentation of the educational material and summary of experiences from first phase field studies. ~M4
D5.5: (Month 30) Updated experimentation plan for second phase field studies. ~M5
D5.6: (Month 36) Presentation of the revised educational material and summary of experiences from second phase field studies. ~M6
Objectives: This work package has two main objectives:

- **Project Management**: This objective comprises the general administrative responsibilities and tasks for coordinating the financial and technical aspects of DEDUCATION to ensure the successful completion of the objectives. This includes ensuring effective implementation of the project in line with guidelines from the Commission, the Project Contract and the Consortium Agreement.

- **Dissemination and Exploitation**: This objective comprises the creation of scientific contributions to the research community, raise public awareness about the project, its expected results and progress within defined target groups using effective communication means and strategies (dissemination) as well as the development of an effectively strategy for exploiting the DEDUCATION results aligned with the market trends, both in terms of overall (joined) and individual partners.

Following the objectives, the work in this work package is organized in two tasks:

**T6.1 Project Management (all partners):** The project management activities need to be adapted to the needs of the project as it evolves, but will include at least the following tasks: organize the communication between the Consortium and the Commission concerning project, set up and run financial accounting and budget reporting processes, coordinate progress reporting within the consortium, continuously monitor progress as well as significant project risks: identify, assess probability and consequences, and devise mitigation strategies. Moreover, this task includes the formal steps needed to obtain approval by Consortium members and the Commission as well as the Constitution of and execution of the project management bodies.

At the start of the project, this task will produce the Project Quality Handbook (D6.1). Thereafter, we will report on the results in this task on a regular basis (D6.2, D6.4, and D6.6).

**T6.2 Dissemination and exploitation activities (all partners):** Dissemination activities aimed at raising public awareness will be undertaken on both collective and individual basis. A dissemination plan will be prepared at the beginning of the project describing dissemination goals, target groups, dissemination channels and individual approach for particular partners. The initial plan will be improved during the project. As one dissemination activity, the consortium will organize international scientific workshops and tutorials on DEDUCATION topics. The workshop will be targeted towards both the academic community and end-users of the DEDUCATION platform and methodology.

We will report on the results in this task on a regular basis (D6.3, D6.5, and D6.7).

| D6.1: (Month 3) Project Quality Handbook | ~M1 |
| D6.2: (Month 12) First Progress Report | ~M2 |
| D6.3: (Month 12) Initial dissemination and exploitation plan | ~M2 |
| D6.4: (Month 24) Second Progress Report | ~M4 |
| D6.5: (Month 24) Second dissemination and exploitation plan | ~M4 |
| D6.6: (Month 36) Final Project Report | ~M6 |
| D6.7: (Month 36) Final dissemination and exploitation plan | ~M6 |
Table 1.3e: Summary of effort

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<th>Partic. no.</th>
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<th>WP2</th>
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1.3.4 Graphical presentation of the components showing their interdependencies

A PERT chart representing the logical dependencies between the work packages is given in Figure 5.

2 Implementation

2.1 Management structure and procedures

2.1.1 General Project Management Principles

General project management of DEDUCATION is based on and characterized by three major principles:

1. Principle of an Integrated Project Structure: Create an integrated project structure that incorporates technical, scientific, and partner coordination as well as issues of commonplace business operation.

2. Principle of Leading Edge Project Management Instruments: Apply internationally operated and state-of-the-art management instruments and establish a strong research commitment of the entire team. The applied project methodology will be based on the methodology of the Project Management Institute (PMI).

3. Principle of Binding Decision Provisions and Agreements upon All Partners: Arrange spot of decision making close to responsible level of execution, elevate if necessary. Provide reliable and trusted agreements to protect intellectual properties of all partners.

Based on these three major principles, the project management approach guarantees transparency and commitment to all partners and thus facilitates an unobstructed and successful project evolution. It assures that DEDUCATION meets its entire objectives in time, on budget, and with supreme quality results.

2.1.2 Project Management Structure

Project Coordinator (UPSud). Prof. Dr. Burkhart Wolff studied from 1984–1990 at the TU Berlin and made his PhD in 1997 at the University of Bremen. From 1997 till 2003 he was Postdoc (wiss. Assistent) at the University of Freiburg, where he got his Habilitation. From 2004–2007 he was “Oberassistent” at the ETH Zürich (in the computer security group led by Prof. David Basin). Since 2008 he is full professor at the Université Paris-Sud and head of the LRI-Group ForTesSE, see http://fortesse.lri.fr/.

Burkhart Wolff has been the initiator of the DFG-project FSA “Formale Sicherheits Architekturen” 1999–2002. He has been project lead of the “Modeling and Verification in UML/OCL” project (funded by ETH, 2004 - 2006), and local project leader of the EU-IP TrustCoM (2005- 2007). He has been initiator and project leader of the project MBT-SEC, (funded by British-Telecom and located at the ETH Zürich, in the
computer security group headed by Prof. D. Basin; 2007–2010). Since 2008, he is leader of the project HOL-TestGen-XT (Chaire Université Paris-Sud and Digiteo Foundation). He is co-ordinating the already mentioned ANR project Paral-ITP (see http://paral-itp.lri.fr/).

Burkhart Wolff has been Chair of the conferences TPHOLs in 2004, TestCom/Fates in 2005, and is Program Chair of Test&Proof as well as ICTSS in 2011. He has been Program Committee Member in ICST, TestCom/Fates, Test&Proof, ICTSS, TPHOLs in the last 5 years as well as in 15 workshops. He published about 50 international publications, among them 10 journal articles (see http://www.lri.fr/~wolff/publications_year.html).

He will be assisted by a professional European project manager of UPSud. His tasks include day-to-day support to the coordinator, including organization and minutes of the meeting, administrative procedures with EC (amendments, official communications, surveys) and within the consortium (e.g., follow-up of administrative and financial documents, communication with partner’s financial staff), updating information on the project website and integration of management, dissemination and financial reports. Further administrative
support, in particular on legal issues (EC procedures, consortium agreement) and financial management with respect to EC rules will be given by the European team of the Technology Transfer Office of PSUD, which gave support to over 100 FP6 and FP7 projects and include specialists of IP issues.

<table>
<thead>
<tr>
<th>Management Body</th>
<th>Responsibilities</th>
<th>Meeting Frequency</th>
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</table>
| Project Coordinator           | • Overall project coordination: monitoring of the progress of the project, detailed budgeting and scheduling of the project plans to be approved by the PCC  
• Day-to-day project communication, between partners and with other parties  
• Monitoring and consolidation of all management and technical reports and deliverables  
• Chairs project coordination committee, prepare and organize the meetings, draft agendas and minutes, and follow-up of the scientific meetings  
• Distribution of community financial contribution, gathering of partners’ administrative and financial document, monitoring of partners spending against budget  
• Only official channel between the consortium and the European Commission and third parties, including coordination and monitoring of GA and CA documents: management of amendments, maintaining Consortium Agreement, reporting all relevant information to the Project Officer | Not applicable |

**Project Coordination Committee (PCC).** The project coordination committee is the highest decision board and its main task is the project governance. The project coordination committee consists of one representative of each partner and is chaired by the project coordinator. It will have the overall responsibility of all technical, financial, legal, administrative, ethical, and dissemination issues of the project. For this reason the project coordination committee will monitor and assess the actual progress of the project and make amendments if necessary. In particular the project coordination committee will be responsible for the following tasks:

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<tr>
<th>Management Body</th>
<th>Responsibilities</th>
<th>Meeting Frequency</th>
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</table>
| Project Coordination Committee| • Approval of IPR-related issues  
• Approval of any change in the Consortium Agreement  
• Approval and acceptance of all project deliverables  
• Review of the project as a whole  
• Approval and acceptance of the implementation plan and adoption of project roadmap (if applicable)  
• Administration and scientific coordination activities  
• Implementation of all action plans  
• Establishing a budget and schedule controlling system  
• Implementation of a quality assurance system  
• Providing clear guidance on IPR issues  
• Developing and maintaining a communication and reporting attitude | Quarterly, on demand |
The PCC will meet at least quarterly. To reduce costs, up to two meetings per year can be conducted remotely using modern communication media.

Project management execution will split up its functions into technological/scientific, administration related and collaboration related tasks for specialization.

1. **Scientific and Technological Coordination**: Those tasks will mainly focus on the various aspects of the scientific and technological activities within the project. A special emphasis within its responsibilities is to assure in accordance with work package leaders the overall integration of the single work packages and the establishment and monitoring of a quality assurance process.

2. **Coordination of Administrative Activities**: Tasks include financial reporting, cost claiming, budgeting, scheduling, intellectual property rights management, management of knowledge dissemination and contract control management. This will be performed by UPSud.

The PCC will execute the process of budget checking during project execution. To allow for financial risk management, all payments to partners will be made against accepted value adding deliverables.

- Partners provide 3/6/9/12 monthly effort reporting to the coordinator for each financial year of the project. At the end of each project 6 months period, partners report estimated costs for the past time period (travel, other).
- Estimated personnel costs are calculated (by the coordinator) based on number of PMs reported for the proceeding time period multiplied by the average PM cost.
- All the work is being evaluated by peer review process which will be defined during the 1st PCC meeting with common agreement of all the partners. After the peer review process, progress of work and/or deliverables are approved by Project Management Board. If the progress of work involving the partner is satisfactory, the partner is paid funding based on the estimated total costs of the time period.
- Progress is evaluated by the WP leaders in terms of the partner’s contribution to progress on planned deliverables.
- The PCC is involved if there are disputes about the amount of progress claimed by the partners.

**Work package Leader.** The work package leaders of DEDUCATION are responsible for managing their work package as a self contained entity. The scope of their responsibilities includes amongst other things coordinating, monitoring, and assessing the progress of the work package to ensure that output performance, budget, and timelines are met. In cooperation with the project coordinator, work package leaders are responsible for the integration of their results into succeeding work packages.

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<tr>
<th>Management Body</th>
<th>Responsibilities</th>
<th>Meeting Frequency</th>
</tr>
</thead>
</table>
| Work Package Leaders| • Management of the work packages  
                      • Coordination, monitoring, assessment, and reporting of the progress of work package  
                      • Quality assurance within WP                                                  | On demand         |

Figure 6 shows the project management structure of DEDUCATION.

### 2.1.3 Management and Information Systems

**Quality Assurance.** Quality expectations for European research projects are very high. Therefore, certain controlling and assessment procedures will be established.

- Establishment of deliverable peer review process: In order to ensure the highest quality of all DEDUCATION deliverables, a clearly structured deliverable process will be established. For quality assurance, this will include two peer review steps, first involving an internal peer who is not involved in the deliverable and second a formal approval from a PCC member (cf. Figure 7).
• Earned value based payments of deliverables: Earned value (EV) is a tracking metric which measures the actual amount of work accomplished, regardless of the effort spent or the time elapsed. The actual amount of work is valued with its budgeted cost. To allow for financial risk management and professional project management, all payments to partners will be made against accepted value-adding deliverables. The general principle of earned value based payments in DEDUCATION aims at half yearly payments, according to the earned value of the deliverables accepted in those six months. This will motivate partners to accomplish deliverables in time and excellent quality.

• Development of communication guidelines and implementation of communication practices: Communication is crucial for the success and quality of EU projects. A dedicated communication plan will be developed and implemented, thus ensuring a close alignment and cooperation between all project partners and WPs.

Early Warning System. State-of-the-art controlling instruments will be applied to support scientific and technology researchers. Those instruments will be accompanied by an efficient communication platform. The co-action of the controlling instruments and the communication platform will create an early warning system to identify quality deviations from the work plan on time. This allows the responsible managers to set up contingency or recovery plans at an early stage.
Communication and Collaboration Platform. Efficient communication and collaboration structures are one of the essentials for the success of the project. Since all project partners are distributed across European member states, the centrepiece of the overall project communication guaranteeing efficient communication will be a protected online collaboration platform. This platform provides each partner access to important documents, code, working documents, meeting agendas, supporting materials and other project information. To ensure the centralization of knowledge and reduction of information retrieval time, the platform will be the store for project related information.

2.1.4 Decision Process and Conflict Resolution

Mandatory decision rules and agreements are necessary for the project success. The decision making process will follow the guideline to reach agreement as close as possible to the level of execution. Only if agreement will not be reached on a given level, the decision will be escalated to the next appropriate level.

- **Decision Scope at Task Level**: All partners being involved in a task are eligible to contribute to a decision regarding that certain task. In case a capable decision cannot be taken at this level, the issue has to be forwarded to the work package leader.

- **Decision Scope at Work Package Level**: All partners being involved in a work package are eligible to contribute to a decision with regards to this work package. In case a capable decision cannot be taken at this level, the issue has to be forwarded to the PCC.

- **Decision Scope of Project Coordination Committee**: The supreme decision committee is the Project Coordination Committee. Each partner has to send a qualified representative to the PCC.

Additionally, specific decision and corresponding voting procedures may be defined in the Consortium Agreement. However, it will be the general effort of all partners and all levels of decisions to achieve solutions representing unity and an overall agreement.

2.1.5 Risk Identification for DEDUCATION

Risks are an inherent element of quality RTD projects. Unmanaged risks may have a detrimental impact on the project schedule and results, and eventually give rise to contractual litigation. The complexity of the technical and technological issues tackled by the project thus requires careful monitoring and management of risks. The management process will identify and monitor risks that could have an impact on the project schedule and results and will take appropriate measures to suppress or mitigate their effects. While some risks (such as too ambitious objectives, technological bottlenecks, or poor integration of competencies) can be identified during the elaboration of the project and adapted strategies devised within the workplan as shown in subsection 1.3, other risks, either internal (e.g. non performing or defaulting partner) or external to the project (e.g. technical developments outside the project, or market evolution) may appear during project implementation and will require timely management decisions. Table 12 and Table 13 present the initial list of risks. These lists are used for starting that process and they will be updated regularly based on experiences in the project. As a general prevention measure we will continuously monitor the project progress in order to detect and react early to any problems that may occur.
Table 12: Technical risks associated to the milestones (and decision points), their probability, and the corresponding management and mitigation strategies

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability</th>
<th>Management and mitigation strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS1: Basic Dissemination and use plan, use cases and State-of-the-art</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure to identify trust and security requirements of problem cases.</td>
<td>low</td>
<td>An appropriate number of PMs have been devoted to the task both from academia and industry so that at least an initial set of trust and security requirements will be identified.</td>
</tr>
<tr>
<td>Adequate use case scenarios can not be selected in time.</td>
<td>low</td>
<td>A task force lead by the case studies workpackage leader AAU will mitigate this risk. The proposal already enumerates multiple directions for use case scenarios, the consortium can chose from.</td>
</tr>
<tr>
<td><strong>MS2: Specification Deliverables</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure to deliver Basic Dissemination and Use Plan.</td>
<td>nil</td>
<td>A basic version of the Dissemination and Use Plan will be delivered in time.</td>
</tr>
<tr>
<td>Failure to chose a suitable policy language to describe security policies.</td>
<td>low</td>
<td>An appropriate number of PMs have been devoted to this task that either an existing language can be augmented or one can be designed from scratch, re-using existing concepts.</td>
</tr>
<tr>
<td>Specification deliverables of the technical WPs 2 to 4 are delayed, endangering the subsequent implementation progress for the prototypes.</td>
<td>moderate/high</td>
<td>The WP lead of each technical WP will closely monitor the progress of the specification activity. A scope reduction that is not critical for the implementation start will be possible, shifting the remaining efforts to the MS5 deliverables.</td>
</tr>
<tr>
<td>Failure to identify a suitable architecture for the DEDUCATION Platform.</td>
<td>low</td>
<td>Some adjustments to the original architecture design might be needed.</td>
</tr>
<tr>
<td>No legal requirements can be identified from the use cases.</td>
<td>low</td>
<td>The legal partner is involved in the use case selection and can influence the choices in an early stage.</td>
</tr>
<tr>
<td><strong>MS3: Prototypes and architecture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure to deliver software prototypes from technical WPs in time, endangering the start of the integration WP5.</td>
<td>moderate/high</td>
<td>The WP lead of each WP closely monitors the implementation progress. The PM distribution among WPs ensures that at least three organizations participate in each technical WP ensuring first the detection of a WP lead’s monitoring lapses and second allowing for delivery of a scope reduced prototype that comes still aligned with the peer WP prototypes.</td>
</tr>
<tr>
<td>A common architecture document can not be compiled in a timely manner.</td>
<td>moderate</td>
<td>Enough PMs of the integration lead UPSud and the partners from the technical WPs have been devoted to WP5. The latter ensures the availability of required expertise to assemble the integrated DEDUCATION architecture.</td>
</tr>
</tbody>
</table>
Table 13: Management/financial risks, their probability, indicators and the corresponding management and mitigation strategies

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability</th>
<th>Indicators</th>
<th>Management and mitigation strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterioration of the economic situation of a partner, that impose a halt or an unacceptable reduction of all activities for that partner</td>
<td>low</td>
<td>Quarterly reporting, partner fails to deliver results</td>
<td>The corrective measures could be to distribute the activity not fulfilled to the remaining partners or to subcontract them to a third party, or a combination of the two. The 2 factors which are reducing this risk are: 1. The current consortium is well complete and most of the activities can be taken over by the consortium in the case of a partner failure. 2. An earned value based payment will be implemented</td>
</tr>
<tr>
<td>Lack of experience in project management (also European Projects)</td>
<td>very low</td>
<td>Project out of scope, budget or time, unsuitable management procedures</td>
<td>The Consortium believes there are no major management risks that could jeopardize the successful development of the project at European level: • UPSud is used to contract management at both national and international levels. UPSud and the other partners of the consortium are used to clear procedures for project management and have sound experience in EU projects. • UPSud has developed its own management plan (management, configuration, quality assurance) which have been widely contrasted in previous projects. The management procedures are therefore very well established.</td>
</tr>
</tbody>
</table>

2.2 Beneficiaries

In the following pages, we give a brief description of each of the project beneficiaries by providing a brief description of each organization, the main tasks they have been attributed (see the work package tables for more details on the role and technical activities of the beneficiaries in the individual work packages), the previous experience relevant to these tasks, and a short profile of the staff members who will be undertaking the work, including information on the new personnel that the beneficiaries plan to hire to carry out the project work.

2.2.1 UPSud: Université Paris-Sud (France)

The University of Paris-Sud XI is the first French university in the Shanghai ranking and second-largest university in France. A number of larger, CNRS-funded research laboratories are associated to it, most notably the Laboratoire de Recherche en of the Informatique (LRI). This Lab belongs to the top 10 research institutions in computer science in France comprising 230 researchers. ForTese http://fortesse.lri.fr/ is a research group inside the LRI comprising 13 members (where 6 are permanent).
Competencies. Main research of ForTesSE is centered around formal software development environments [18, 22, 16], in particular in the field of verification and formal testing [19, 23]. This motivated continued research for the pervasive parallelization of Isabelle [77, 52, 80], which used routinely in a major system of the group, the Isabelle application HOL-TestGen [23, 19]. With the integration of Makarius Wenzel into the group, substantial know-how for Isabelle system development was added. This combines to previous work to transform Isabelle in a Formal Methods Tool-framework [82]. Burkhart Wolff and Makarius Wenzel have both a long-standing interest in user-interface technologies [47, 78, 83]. This line of research lead to substantial contributions in the PIDE framework and the creation of the aforementioned ANR project Paral-ITP http://paral-itp.lri.fr/.

Role in the project. UPSud will provide the key-component of the project: the DEDU-Framework. It will provide contributions to dissemination (extensive documentation, a series of tutorials, “Isabelle-Developer-Workshops,” and several prototype “reference PRTEs,” a developer mailing list). An extensive technical support for WP 2 and WP 5 (technical support for assessment infrastructures) is also provided. UPSud will also provide a server for dissemination (for project material, downloads, PRTE-hosting). Last but not least, UPSud leads the WP 6 (Management and dissemination); for this purpose, we will hire half-time an experienced officer for the duration of DEDUCATION (potentially shared with another EU project of UPSud).

Interest in project results. The main interest of this partner is to enhance the ITP technologies both wrt. modeling, parallel symbolic computation and asynchronous proof processing, such that decades of research in theorem proving will become more easily accessible for the construction of trustworthy software as well as educational systems referring to mathematics or other forms of managed formal content.

Key personnel. Prof. Dr Burkhart Wolff is head of the ForTesSE-team since 2008, a group with a traditionally strong emphasis on formal methods in software engineering. His research interests are in the field of modeling and model-based software development by validation and verification, be it for proof or systematic test. A special interest is the construction of correct tools — based on interactive and automated theorem proving techniques.

Dr. Makarius Wenzel, coming from the Isabelle group at TU Munich, while remaining its chief-technical officer (CTO), continued his work on Isabelle: substantial parts of the PIDE framework and the jedit client have been implemented at UPSud. This constitutes a first usable implementation of an IDE front-end that is currently part of the Isabelle2011-1 distribution.

Nicolas Lecompte is the EU-officer of UPSud and will be involved in the setup-phase of the project as well as consultant of the project manager officer when the project is under way.

2.2.2 UdS: Université de Strasbourg (France)

With about 45,000 students, the University of Strasbourg is one of the largest university in France. The Image Sciences, Computer Sciences and Remote Sensing Laboratory (LSIIT) is a mixed research unit of the CNRS and of the University of Strasbourg. It is an interdisciplinary laboratory federated by the image and one of the major research topics is Computer Science. The team Computer Graphics and Geometry (IGG) is a research group of the LSIIT comprising 20 permanent members.

Competencies. Research, within the group, explore geometry and its involvement in shape modeling, formal specification, resolution of geometrical constraint systems and geometry proofs. Julien Narboux and Pascal Schreck have a long standing interest in applications of these research field to build education prototype tools to build user interface for education [34, 54]. The group was involved in the French ANR
project Galapagos (2007–2011) dedicated to formalization of geometry and computational geometry with applications in education.

**Role in the project.** This partner will mainly focus on contributing to WP3 in cooperation with UC and FMUBg to provide a formalization of geometric constructions and certified tools to build constructions automatically. Based on this foundational work it will contribute to the development of a PLE for geometry constructions problems using PIDE.

**Interest in project results.** This partner has a long standing interest in building a tool for interactive proof in geometry to validate our intuition and demonstrate that the proving process can be taught better using such a tool.

**Key personnel.** Pascal Schreck is Professor at University of Strasbourg. After teaching mathematics for four years in high-school, he received in 1992 a PhD in Computer Science from University of Strasbourg. Pascal Schreck has strong expertise about geometric constraints solving and generation of construction plans with application in the education. He implemented Projé a tool to generate geometric constructions automatically [68]. Since 2006, Pascal Schreck is co-organizer together with Dominique Michelucci and Xiao-Shan Gao of a session dedicated to constraints and geometrical reasoning which is part of the conference ACM SAC (Symposium on Applied Computing). Pascal Schreck and Julien Narboux have been the co-chairs of the conference ADG 2010. Pascal Schreck was the head of department of computer science (2008-2011). Julien Narboux is Assistant-Professor at University of Strasbourg. He holds a PhD in Computer Science from University Paris XI which is received in 2006. Julien Narboux works on the formalization and automation of geometry using a proof assistant. He has implemented the software GeoProof: an interactive system for proof in geometry [54]. He formalized two ATP methods for geometry in Coq: Wu’s method and the area method [36, 42].

2.2.3 DFKI: **GERMAN RESEARCH CENTER FOR ARTIFICIAL INTELLIGENCE (Germany)**

Founded in 1988, DFKI today is one of the largest nonprofit contract research institutes in the field of innovative software technology based on Artificial Intelligence (AI) methods. DFKI is focusing on the complete cycle of innovation — from world-class basic research and technology development through leading-edge demonstrators and prototypes to product functions and commercialization. Based in Kaiserslautern, Saarbrücken, and Bremen, the German Research Center for Artificial Intelligence ranks among the important “Centers of Excellence” worldwide. The key directors of DFKI are Prof. Wolfgang Wahlster (CEO) and Dr. Walter G. Olthoff (CFO).

**Competencies:** The Cyber-Physical Systems research department (CPS) of DFKI in Bremen has competence in the development in the development of user interfaces for theorem provers, and applications of proof assistance systems for step-based tutoring of mathematical proofs. For EDUCATION, we will build on previous work in the area of user interfaces, and work in the projects OMEGA [3] and DIALOG [15] of the Collaborative Research Centre 378 “Resource-adaptive cognitive processes”\(^2\).

**Role in the project.** DFKI will lead and substantially contribute to WP 2, building on their previous work in developing user interfaces for theorem provers. DFKI will further contribute to WPs 3 and 4 by developing components for proof step analysis and next-step hint generation as part of a tutor to teach mathematical proofs.

\(^2\)http://www.coli.uni-saarland.de/projects/sfb378/
**Interest in project results.** An important element of DFKI’s mission is to move innovations as quickly as possible from the lab into the marketplace. Only by maintaining research projects at the forefront of science such as DEDUCATION DFKI has the strength to meet its technology transfer goals. In particular, adequate user interfaces as developed in DEDUCATION for formal method tools as developed by DFKI are the key to the adoption of formal methods in industry; DEDUCATION will greatly enhance DFKI’s project acquisition capabilities with industry.

**Key personnel.** Dr. Serge Autexier is a senior research at the research department. He received his PhD in foundations of proof assistant systems from the Saarland University, Germany in 2003. He works in the areas of formal methods, proof assistant systems and change impact analysis, was project leader of the OMEGA-project [3], and is a trustee of the Mathematical Knowledge Management interest group.

Prof. Christoph Lüth is vice director and manager of the research department. He works in the areas of formal methods, functional safety, software verification, and user interfaces for theorem provers, where together with Burkhart Wolff he designed an implemented a graphical desktop interface for the Isabelle theorem prover.

**Receipts:** The partner DFKI plans to use resources made available by third parties (i.e. the state of Rhineland-Palatinate, the states Saarland and Bremen). The resources include salaries of professors and researchers paid by the governments, as well as equipment, infrastructure and services paid by the governments. The total amount of such receipts will be 25200 Euro and be allocated to the DEDUCATION project.

**2.2.4 SAP: SAP AG (Germany)**

SAP is the world’s largest inter-enterprise software company and the world’s third-largest independent software supplier. SAP solutions help enterprises of all sizes around the world to improve customer relationships, enhance partner collaboration and create efficiencies across their business operations. SAP employs over 39,300 people in more than 50 countries. SAP Research is the technology research department of SAP and is responsible for identifying, researching, understanding, developing and evaluating new and emerging technologies that influence the future of SAP business applications. SAP Research is a Business Unit under the direction of SAP AG. In the context of this document, SAP refers to SAP AG and its SAP Research Business Unit.

**Competencies.** SAP will contribute with its expertise software development for large enterprise systems in particular with a focus on using formal methods for ensuring their security and safety of software systems. Moreover, SAP will contribute its expertise in teaching programming and software related topics to more than 15,000 developers and architects at SAP. Moreover, SAP Research is or was involved in several European and national projects relevant to DEDUCATION, among them Aniketos [2], AVANTSSAR [5], SPACIOUS [72], and Deploy [30].

**Role in the project.** SAP will focus on WP4 by developing a textual PRTE for teaching secure and safe programming techniques. Moreover, SAP will contribute to the industrial exploitation and dissemination of DEDUCATION.

**Interest in project results.** Overall, the results of DEDUCATION will extend SAP’s expertise in teaching the necessaries skills required for developing secure service-oriented enterprise systems that fulfill the customers’ requirements. In particular, DEDUCATION will contribute to SAP’s central security initiative that, among others, governs all security relating teaching initiative within SAP. Moreover, DEDUCATION
will help SAP in evaluating the use of mathematical-based techniques for developing and teaching software engineering techniques in an industrial environment.

**Key personnel.** Dr. Achim D. Brucker is a Senior Researcher at SAP Research in Germany where he is contributing to the Security and Trust Research Practice. His research interests include security, software engineering and formal methods. In particular, he is interested in tools and methods for modeling, building, and validating secure and reliable systems. He contributed to the development of several tools based on Isabelle/HOL (e.g. HOL-TestGen [21], HOL-Z [18], HOL-OCL [20], and Isabelle/OFMC [17]). He also participates in the OCL standardisation process of the OMG.

Dr. Martin Johns joined in 2005 the “Security in Distributed Systems” group at the University of Hamburg to work on web and software security topics. Since December 2009, he holds a position as researcher at SAP Research in Karlsruhe, Germany.

### 2.2.5 JKU: Johannes Kepler University Linz (Austria)

The Johannes Kepler University (JKU) Linz is the largest academic institution in the federal state of Upper Austria. The Research Institute for Symbolic Computation (RISC) is part of the JKU but located in the Castle of Hagenberg 20 km from Linz.

**Competencies.** Founded by Bruno Buchberger and currently directed by Peter Paule, RISC has pursued for two decades research on computer algebra, computational geometry, computational logic, automated reasoning, constraint solving, functional and logic programming, formal methods, and parallel processing with various applications in technical sciences. The institute has a faculty of 17 members with doctoral degree and several PostDoc researchers. Apart from numerous diploma students of computer science and computer mathematics, about 25 (mostly foreign) Ph.D. students pursue their research at RISC. RISC has been participating in numerous national and international projects, e.g. the EU project FP6-I3-026133 SCIEnce (Symbolic Computation Infrastructure for Europe). The participation in this project will be pursued by the Formal Methods group at RISC (Wolfgang Schreiner) in association with TUG (Walther Neuper, Christian Guetl) and in collaboration with the Automated Theorem Proving group at RISC (Theorema project, Bruno Buchberger and Tudor Jebelean).

**Role in the project.** JKU/RISC coordinates WP 4 “Textual PRTEs”; its own contribution to this work package consists in the subtopic of “Mathematics with Next Step Guidance” which aims to revise Neuper’s T$\mathcal{S}$AC-environment (see below) for integration into the DEDU framework. For this purpose, the T$\mathcal{S}$AC session interface is remodeled to make use of the PIDE’s document model for remote interaction with the DEDU core; the goal is to use this core to formally validate the simplification steps performed by the user respectively to ultimately guide the user in this process.

**Interest in project results.** The main interest of JKU/RISC is to automate symbolic methods such as theorem proving and integrate them into software environments that aid research, education, and industrial practice in mathematics and computer science. The results of the project will become an important cornerstone also for future activities and further software components developed by JKU/RISC that can be integrated into the DEDU framework.

**Key personnel:** Wolfgang Schreiner is the principal developer of the RISC ProgramExplorer, a semantics-based program reasoning environment for educational purposes [70, 69]. He has earned in 2001 habilitation in practical computer science and has been working at the RISC institute in the areas of formal methods and parallel and distributed computing. He is currently the scientific director the FFG BRIDGE
project “LogicGuard”, was directing in 2009–2011 the FWF Doctoral College DK W1214 project “Formally Specified Computer Algebra”, and in 2009–2011 the RISC participation in WP JRA1 of the EU Project SCIEnce.

Walther Neuper directs since 1997 the development of ISAC [44], an educational mathematics assistant for engineering applications; he implemented the ISAC-prototype’s mathematics engine based on the ITP Isabelle, comprising an ITP-based programming language and an interpreter for this language, later called “Lucas-Interpreter”; he also supervised the development of a Java-based front-end for the mathematics engine which proved successful in field-tests at Austrian schools in 2006–08. Since 2008 Walther Neuper focuses on establishing “ITP-technology for educational software” as an academic topic.

2.2.6 UC: UNIVERSIDADE DE COIMBRA (Portugal)

The University of Coimbra, established in 1290, is one of the oldest universities in continuous operation in the world, the oldest university of Portugal, and one of its largest higher education and research institutions. The University of Coimbra and its research centers are a Portuguese and international reference in the production of science, in many fields. Among those research centers are the Centre for Mathematics of the University of Coimbra (CMUC) and the Centre for Informatics and Systems of the University of Coimbra (CISUC).

Competencies. The Department of Mathematics of University of Coimbra offers degrees in Pure and Applied Mathematics, Computer Science and Mathematics Education. The research at the Department of Mathematics is developed in most of current areas of modern mathematics, ranging from applied fields — such as numerical analysis, computational mathematics, statistics or optimization — to more theoretical subjects, as algebra, mathematical analysis or geometry. The scientific production of the researchers at the Department of Mathematics has received the highest classifications from the international evaluation committees held by the Fundação para a Ciência e Tecnologia, the Portuguese funding agency for science and technology.

The Centre for Mathematics of the University of Coimbra (CMUC) is a research unit with interests in pure and applied mathematics. CMUC is actively involved in research as well as in postgraduate education.

The Centre for Informatics and Systems of the University of Coimbra (CISUC) is a large Portuguese research centre in the fields of Informatics and Communications, which was created in 1991 under the Program Science. CISUC aims at carrying out original R&D at a pre-competitive level, training highly qualified young researchers, co-operating in national and international projects and programs, and promoting the dissemination of results by means of contracts with different companies.

Role in the project. The members of the UC working in this project will focus on contributing to work package WP3 (Visual PRTEs) contributing to the development of a visual PRTE for geometry and to work package WP5 (Case Studies and Empirical Evaluation) contributing to the analysis of requirements, the design of empirical case studies and its execution in Portuguese high-schools.

Interest in project results. This partner has a long standing interest in providing a repository of geometric problems that can be useful for the dynamic geometry software and geometry automated theorem proving communities. We are also very interested in building a learning environment for geometry capable to integrate dynamic geometry software tools, geometry automated theorem provers and repositories of geometric problems.

Key personnel: Pedro Quaresma is an assistant professor at the Department of Mathematics and a researcher in the Centre for Informatics and Systems (CISUC), he is a mathematician with a PhD degree
in Computer Science given by the Minho University. His area of expertise is the automated deduction in geometry where, in collaboration with Predrag Janičić and Julien Narboux, he already developed and implemented some systems (e.g. GeoThms\(^3\) and TGTP\(^4\)) and with an extensive publication record in the area. He has Vanda Santos as his PhD Student in the area of Learning Environment for Geometry already with many publications in this area, currently developing the Web Geometry Laboratory (WebGeometryLab\(^5\)). He is, along with Ralph-Johan Back, chair of the THedu (Computer Theorem Proving components for Educational Software) interest group and chair of the THedu’11 workshop (at CADE23), and THedu’12 workshop (at CICM2012).

Jaime Silva is an associate professor at the Department of Mathematics, a researcher in the Centre for Mathematics (CMUC) and he is the current Secretary General of the International Commission on Mathematical Instruction (ICMI). He has a long and intense experience in the preparation of future mathematics teachers and in the Mathematical education area in general.

### 2.2.7 AAU: Åbo Akademi University (Finland)

Åbo Akademi University (AAU) is an internationally acknowledged research university in Turku, Finland. The Department of Information Technologies (IT) at AAU provides education in computer science, computer engineering and information systems; it has eleven full professors, about 50 doctoral students and about 600 undergraduate students. The department has been involved in over 70 major research projects since 2006, including six ongoing European Union projects, 16 ongoing Academy of Finland projects, and eleven ongoing projects funded by the Finnish Funding Agency for Technology and Innovation (TEKES).

#### Competencies.

The principal members of the group are Ralph-Johan Back (group leader), Johannes Eriksson (senior researcher), Linda Mannila (senior researcher), Viorel Preoteasa (senior researcher), and Charmi Panchal (Ph.D. student). Group members are active in the Software Construction Laboratory, researching techniques for reliable software construction, and in the Learning and Reasoning Laboratory, focusing on improving reasoning and teaching methods in mathematics and programming. Both laboratories have conducted research on the foundational as well as the educational aspects of both structured derivations [8, 11, 61] and invariant-based programming [7, 12, 10, 9].

#### Role in the project.

AAU will be involved in textual PRTE:s (WP4) with the task of implementing front-end tools for structured derivations and invariant-based programming. The group will additionally be in charge of the empirical evaluation of several PRTE:s (WP5), encompassing requirements analysis, execution in high schools and universities, and collection and evaluation of feedback.

#### Interest in project results.

The first aim of AAU is to enhance the front-end tools for structured derivations and invariant-based programming with the capabilities of the DEDU framework, in order to improve the reliability, reasoning power and ease of use of the tools. The second aim is to understand, through the empirical studies, how the evaluated PRTEs can be efficiently applied in educational scenarios.

#### Key personnel:

Ralph-Johan Back is Professor of computer science at AAU. He received his Ph.D. in computer science from the University of Helsinki in 1978. He is well known for developing the refinement calculus and establishing its mathematical basis in lattice theory. His main interests are formal methods, distributed and parallel systems, multiprocessor technology, software engineering and teaching of mathematics and programming. He has been the leader of several projects related to computer-supported teaching.

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\(^3\)http://hilbert.mat.uc.pt/GeoThms  
\(^4\)http://hilbert.mat.uc.pt/TGTP  
\(^5\)http://hilbert.mat.uc.pt/WebGeometryLab

Johannes Eriksson holds a Ph.D. in computer science from AAU; he is the main developer of Socos, an IBP environment with ATP and ITP support. Linda Mannila holds a Ph.D. in computer science from AAU; her research focuses on teaching of basic programming and algorithmic thinking to high school and first year university students. Viorel Preoteasa holds a Ph.D. in computer science from AAU; his research centers around ATP & ITP, theory of programming, and teaching programming and mathematics.

2.2.8 FMUBg: Matematički fakultet, Univerzitet u Beogradu (Serbia)

The University of Belgrade is the oldest and largest state university in Serbia. As an individual department, Faculty of Mathematics has been founded in 1873. Around 300 undergraduate, 200 master, and 75 PhD students are enrolled each year in one of the available study programmes (mathematics, computer science and astronomy). Numerous graduates occupy positions in research institutions, government offices, companies and schools in the country and abroad. The Automated Reasoning Group (ARGO) from the Faculty of Mathematics is led by professor Predrag Janičić and has 10 members.

Competencies. The ARGO group’s research interests are in automated reasoning, especially in the use of decision procedure in automated reasoning systems, in satisfiability modulo theories, geometry reasoning, and in interactive theorem proving. The group has expertise in automated geometry theorem proving [41, 74]. GCLC [41] (developed by Predrag Janičić since 1996) is a tool for visualizing and teaching geometry, and for producing mathematical illustrations. GCLC provides support for three most efficient methods for GATP (Wu’s method, Groebner bases method, the area method). The group members are also involved in formalization of procedures for automated theorem proving, like the area method for geometry [42] or methods for SAT solving [50, 48, 49, 51]. The group organizes an annual international Workshop on Formal and Automated Theorem Proving and Applications. The group members have published a number of papers in leading international conferences and journals.

Role in the project. FMUBg will focus on contributing to WP3 by developing automated solvers for geometry construction problems and open source geometry automated theorem provers. The members will work on integration of these tools into the PLE for geometry construction problems. Additionally, FMUBg will contribute to the empirical evaluation (WP 5) as well as the management and dissemination (WP 6).

Interest in project results. The central interest of FMUBg is to develop and improve automated reasoning methods in geometry and integrate them into the DEDU framework, making them available for use in education and enabling their formal analysis and verification.

Key personnel: Predrag Janičić, associate professor at FMUBg, holds a Ph.D. in computer science, which he received in 2001 from the University of Belgrade. His research interests are in automated reasoning and in mathematical software, especially, in SAT solving, SMT solving, and in automated deduction in geometry. He has led the national project “Automated reasoning and advanced processing of huge amounts of data and text” (ON144030, 2006–2010.) and is currently leading the national project “Automated reasoning and data mining” (OI174021). He is co-leading a bilateral (Swiss-Serbian) research project “Decision procedures: from formalization to implementation” (SCOPES IZ73Z0_127979/1) and is a MC Member of COST Action “Rich models toolkit” (IC0901).

Filip Marić, assistant professor at FMUBg, holds a Ph.D. in computer science, which he received in 2009. from the University of Belgrade. His main research interests are in interactive and automated the-
orem proving with applications to formalizing mathematics and software verification and SAT/SMT solving with applications to optimization problems.

2.2.9 Associated Partner: Graz University of Technology (Austria)

The Institute for Information Systems and Computer Media (IICM) at Graz University of Technology has a long tradition in research and development of multimedia information systems for various application domains, such as digital libraries, knowledge management systems, e-education systems, and new media technologies. The Advanced Educational Media Technology Group (AEMTG) focuses on adaptive e-learning, e-assessment, and the application of computer media for learning and training (such as virtual 3D worlds and mobile devices).

Competencies: As e-education and e-assessment have an highly interdisciplinary research focus, the AEMT group brings together expertise in computer science, information systems, usability as well as pedagogic and cognitive science. The research interest of the AEMT Group includes adaptive systems for collaborative and distance education with a strong focus on natural education. The second research strand is on e-assessment, where the group focuses includes activities on a flexible assessment infrastructure, (semi-)automatic test item creation and assessment, providing advanced feedback for teachers and students, and researching smart guidance approaches. Group members have long lasting experiences in EC projects (such as PROLEARN); the AEMT group is involved in ALICE (complex learning experience and new assessment methods) on assessment and organizes the Special Track on Computer-based Knowledge & Skill Assessment and Feedback in Learning Settings (CAF) since 2008. AEMT has established international collaborations with the MIT (Boston) and CUNY (New York) in USA, Curtin University of Technology, Western Australia, and UTS in Sydney.

Role in the Project: TUG will perform an extended field study on next-step-guidance (WP4) in engineering studies (faculty of electrical engineering, structural engineering, mechanical engineering and signal processing). This study will connect lectures on mathematical basics with labs relying on these basics in higher semesters by using one and the same software in different dialog modi. The AEMT group will observe this study based on their specific knowledge in e-learning, usability, pedagogic and cognitive science, and AEMT will serve with contribution to feedback in this study.

Interest in project results. In case of success of the above mentioned field study TUG plans to use the PRTE in engineering education on a regular base. Furthermore, the AEMT group will use DEDUCATION’s PRTEs as tools for their ongoing research on assessment and on adaptive systems; of particular interest is the PRTE with next-step-guidance, exploiting DEDUCATION’s mechanisms for data collection.

Key personnel: Christian Gütl is chief scientist and head of Advanced Educational Media Technologies Group; he received the “venia legendi” for applied computer science in 2009 and holds a PhD in computer science; he was project manager of several large industry projects, author of more than 120 peer-reviewed book chapters, journal and conference proceedings publications. Research areas: information search and retrieval; e-education & e-assessment, virtual worlds for learning and knowledge transfer; he is also initiator and co-chair of the ViWo workshops; co-founder of the E-iED and board member of the GOLC consortium; he is also adjunct research professor at Curtin University in Australia.
2.2.10 Associated Partner: The Geogebra Group (Austria)

The Department of Mathematics Education (http://www.jku.at/idm), chaired by Prof. Markus Hohenwarter, is integrated into the Faculty of Engineering and Natural Sciences, and is one of ten mathematics departments at the Johannes Kepler University Linz. The Faculty offers programs for students of (applied) mathematics as well as for students of mathematics education, the latter of which are catered for by the staff of the Department of Mathematics Education. The department offers all relevant courses on mathematics education for students enrolled in the program for secondary school teachers of mathematics including courses on the use of ICT for learning and teaching as well as the creation of interactive educational materials. Furthermore, the Department of Mathematics Education has a long tradition of close collaboration with experienced classroom teachers who are both involved in teaching courses for preservice teachers as well as active members of research projects.

Competencies. The research focus of the Department of Mathematics Education is on the creation and use of open educational resources, in particular connected to the open source dynamic mathematics software GeoGebra, which was invented by the department’s chair, M. Hohenwarter. Recent projects dealt with the creation of online courses based on open educational resources, the development of a computer algebra extension for the software GeoGebra, and the establishment of a local community of practice of teachers and researchers between various schools and teacher education institutions in order to support the effective use of ICT in mathematics teaching in Austria.

Furthermore, the Department of Mathematics Education at the Johannes Kepler University Linz is leading the International GeoGebra Institutes (IGI, see http://www.geogebra.org/igi/), a global network of local groups of volunteering teachers and researchers working together at more than 50 universities. The main goals of IGI are the support of professional development for teachers, software development, and research projects concerning open educational resources around GeoGebra. In Linz, a team of more than 15 students, teachers, and researchers is currently actively involved in local professional development events, conferences, and research projects as part of this community.

Role in the project. Markus Hohenwarter is the creator of GeoGebra, an open source software used as JVM-based rich client application by DEDUCATION. He and his team will cooperate in the conception of the interfaces between PRTEs and the DEDU framework, in particular the abstraction of geometric constructions such that they conform to the DEDU document model.

Interest in project results. In case DEDUCATION’s solution for the interface meets the strategic lines of GeoGebra’s product development, GeoGebra would integrate it into its products and take profit from DEDUCATION’s TP-services. On the other hand DEDUCATION would achieve additional impact by dissemination of services and components via the world-wide active GeoGebra Institutes. 6

Key personnel: Markus Hohenwarter.

2.3 Consortium as a whole

The consortium combines 6 partners from academia (UPSud, UdS, JKU, UC, AAU, FMUBg), 1 partner from other research and education institutes (DFKI), and 1 partner from industry (SAP). As a whole, the consortium provides the project with the expertise and experience in all the key areas that are required to achieve the project’s objectives. The partners’ core competences (see Table 14) are complementary to each other. Each partner represents a unique contribution to the project; there is no partner that can automatically

6 http://www.geogebra.org/igi/
Table 14: Competences of the beneficiaries

<table>
<thead>
<tr>
<th>Benef.</th>
<th>Expertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UPSud / LRI has the key competence in Isabelle and Coq kernel development as well as knowledge in asynchronous, fine-grained checking of (generic) document models. It has longstanding experience in formal methods tool development.</td>
</tr>
<tr>
<td>2</td>
<td>UdS has key competence in the domain of formal interactive and automated proof in geometry, solving of construction problems. It built a prototype for interactive proof in geometry based on Coq.</td>
</tr>
<tr>
<td>3</td>
<td>DFKI has competence in design and development of user interfaces for theorem provers, as well as typical applications of theorem provers in verification, computer mathematics and education.</td>
</tr>
<tr>
<td>4</td>
<td>SAP is the recognised leader in service-oriented enterprise systems and architectures. It offers expertise in security for open, heterogeneous, and adaptive enterprise systems, business processes, and services, in trust management for collaborative web environments and virtual organizations, and in formal methods for security.</td>
</tr>
<tr>
<td>5</td>
<td>JKU/RISC has a long standing expertise in computer mathematics and formal methods with focus on symbolic techniques (computer algebra, automated theorem proving); both JKU Linz (RISC) and TU Graz have worked since long on the application of theorem proving techniques to computer-supported mathematics education.</td>
</tr>
<tr>
<td>6</td>
<td>UC has expertise in developing geometric automated theorem provers and in the development of web interfaces connecting dynamic geometry softwares, geometric automated theorem provers and repositories of geometric problems in researching and also in educational settings. UC has also a long and intense experience in the preparation of future mathematics teachers and in the Mathematical education area in general.</td>
</tr>
<tr>
<td>7</td>
<td>AAU/IT Dept. has substantial expertise in programming methodology, mechanical theorem proving and the teaching of mathematics and programming. The IMPEd resource center, founded in 2007 jointly with the University of Turku, researches and disseminates new ideas and methods for teaching basic mathematics and programming at different education levels.</td>
</tr>
<tr>
<td>8</td>
<td>FMUBg has expertise in developing dynamic geometry systems, automated theorem provers for geometry, and in formal interactive verification of automated theorem proving methods (e.g., SAT and SMT solvers).</td>
</tr>
</tbody>
</table>

take another partner’s role and tasks. The partners are suited and strongly committed to their tasks (see Table 15) and their competencies match the tasks they have been assigned to in the project. Since its partners come from very different parts of Europe, the DEDUCATION consortium captures the diverse requirements that emerge from various educational and cultural aspects in Europe. Variety in type of organization and in geographical location of DEDUCATION partners ensures that project results will reach communities and countries across Europe, beyond the borders of EU (since Serbia is not an EU member). Since many partners are academic institutions, live communication with students is easily established and students can give immediate feedback on the main DEDUCATION results.

All the partners have participated (and several have coordinated) EU projects in the past. All partners have a commitment to applying standards, contributing to standardisation, as well as using and contributing to open source software.

All the partners are equal opportunity employers and the consortium strives for a representative participation of female employees in the project. This is however challenging due to the low percentage of female students in technical studies (approx. 15–20% in computer science).
Table 15: Main tasks attributed to the beneficiaries

<table>
<thead>
<tr>
<th>Benef.</th>
<th>Name</th>
<th>Main tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>UPSud</td>
<td>Consortium lead, also leading WP 1 and WP 6 (Management and Dissemination). Provider of DEDU Platform and resulting dissemination material.</td>
</tr>
<tr>
<td>2</td>
<td>UdS</td>
<td>Lead of WP 3, provider of logical foundations of graphical PRTEs.</td>
</tr>
<tr>
<td>3</td>
<td>DFKI</td>
<td>Lead in WP 2, provider of web-based PRTE-components as well as components for faulty proof analysis and next-step hint-generation for textbook-mathematical proofs.</td>
</tr>
<tr>
<td>4</td>
<td>SAP</td>
<td>Provider of PRTE for program-based testing, industrial exploitation</td>
</tr>
<tr>
<td>5</td>
<td>JKU</td>
<td>Lead in WP 4, provider of PRTE for mathematics with next-step-guidance.</td>
</tr>
<tr>
<td>6</td>
<td>UC</td>
<td>Integration of libraries of Geometrical Problems.</td>
</tr>
<tr>
<td>7</td>
<td>AAU</td>
<td>Lead in WP 5, provider of PRTE for structured derivations, provider of PRTE for invariant-based programming.</td>
</tr>
<tr>
<td>8</td>
<td>FMUBg</td>
<td>Provider of a PRTE for geometric reasoning.</td>
</tr>
</tbody>
</table>

Sub-contracting

The only two subcontracting foreseen in this project:

1. For some of the partners, a financial auditing is required. The preparation of the required audit certificates will be sub-contracted to financial audit firms.

2. Software-Maintenance. The underlying PolyML compiler of the Isabelle-System is maintained by Prolingua LTD (Edinburgh) http://www.prolingua.co.uk/. This kind of maintenance is intended to improve the PolyML Platform underneath Isabelle. In particular, such a Software-Maintenance-Contract is useful to port the platform to more advanced multi-core platforms available during runtime of DEDUCATION.

Other countries

There are no consortium members from countries outside the EU Member States and Associate States.

Additional partners

All partners needed to form an appropriate consortium for the DEDUCATION project are identified and included in this proposal.

- **Graz University of Technology (TUG)** is the site where the \( \mathcal{L}S4C \) system was originally developed by Walther Neuper and others; in WP4 this system will be further elaborated and integrated with the DEDU framework by partner JKU (Schreiner and Neuper); the role of TUG as an associated partner of DEDUCATION is mainly to provide feedback on the assessment activities of the project (WP5) respectively the corresponding technical components (WP1).

- **The GeoGebra Group** is affiliated to the same university as JKU, supports the use of their open source Dynamic Geometry System for a visual PRTE in WP3 and will cooperate in the definition of the interfaces between PRTEs and DEDU framework in T3.1 (together with T4.1).
2.4 Resources to be committed

The descriptions in this proposal demonstrate a realistic assessment of the efforts necessary to effectively realize our plans. This is in particular reflected in summaries of staff effort and efforts attributed to the different work-packages. As shown in 1.3.3, the project will require a total of 598 person months, distributed between the two principal kinds of activities as follows:

- RTD: 564 person months for research and innovation, and
- Management: 34 person months for project and consortium management and dissemination activities.

Moreover, as shown below, the distribution of grant for RTD activities well balanced between partners (see Figure 8a) and countries (see Figure 8b):

![Breakdown of Grant for RTD WPs](image1)

![RTD grant breakdown per country](image2)

Figure 8: Distribution of grant for RTD activities

Research and innovation

**Personnel.** As can be seen from form A3 of the proposal, the vast majority of the planned costs will cover personnel costs for RTD. However, 16 person months will be devoted to dissemination of the project results and migration of our technologies into scientific research communities devoted to education and theorem proving (a list of scientific conferences where partners publish regularly is shown in 3.2.2). Moreover, as explained in the impact part, all partners of the project contribute to the Dissemination activities, which is devised as to enhance the potential for an effective exploitation of PRTEs in education, editor houses for schoolbooks and education legislators.

In addition, activities oriented towards the general public are planned.

**Travel.** Travel will be fundamental not only for the dissemination of our results but also, and most importantly, for ensuring the tight synergy between the consortium partners and the intense exchange and cross-fertilisation of ideas and results required by the project. Hence, all partners have requested substantial funding for travelling to such project-internal technical meetings, as well as to external meetings (conferences, workshops, industry days, etc.) where the project results will be presented.

**Equipment.** The equipment costs will be limited to 10 k EUR for the acquisition of hard- and software necessary for common DEDUCATION portal. The portal will play a key role as dissemination platform and knowledge repository within the project. Moreover, it will be used to host the web-based PRTEs. Last but not least, it will also host the DEDUCATION website.
Management

Resources for project management are adequate (less than 5% of the total requested grant). The project coordination and management will be carried out by the project coordinator UPSud. The management costs have been kept to the minimum required for the smooth course of the project and the assessment of its scientific and administrative progress (via the required internal and external audits). As remarked above, the only subcontracting foreseen in the project is for auditing reasons, and thus very limited.

Resources complementary to EC contribution

In addition to the funding requested from the EC, all partners will bring their own resources to the project (for the budget complementary to the requested EC contribution). This includes both the technical work to be provided by permanent scientific staff members and the administrative support from the local offices, as well as the hardware and software necessary for the successful completion of the project (except for the equipment mentioned above).

Third parties

We thus believe that the overall financial plan is adequate for such an ambitious workplan: the relatively high funding requested is justified by the scope and objectives of the project, which require a consortium that integrates state-of-the-art academic and industrial experience such as ours.

3 Impact

3.1 Expected impacts listed in the work programme

DEDUCATION contribution to the expected impacts listed in the work programme:

- **Unlock the potential of the individual by a stronger and smarter adaptation and personalization of educational technologies.** DEDUCATION’s PRTEs achieve a high level of adaption and personalization more efficiently than traditional uses of educational technologies, because they build upon TP-based technology which provides automation in checking stepwise problem solving; these checks are logically reliable and provide the general basis for building user-models, handling misconceptions, etc. Consequently, individual students can be offered their own personalized learning paths, allowing them to move forward through material and tasks in an order that is near to optimal for them.

- **Significantly higher level of effective, personalized, ICT-based tutoring, leading to its wide-spread penetration in schools and at home.** DEDUCATION’s PRTEs provide uniform software support covering the whole process of problem solving. As a result, tutoring provided by the PRTEs comprises all steps involved in solving a problem which make them suitable for a multitude of use case scenarios: self study, homework, additional challenges for interested students, etc. The feedback provided and the data collected by the PRTEs give both students and teachers accurate information about student performance (what topics are easy, where do students run into problems, etc.). The PRTEs leave more time for teachers to focus on individual guidance and areas which students evidently have difficulties with. DEDUCATION serves as a test environment for the PRTEs, giving good opportunities for showing how TP-based authoring can be used in mathematics education. If the technology is proven to work on a small scale, mechanized tutoring of complete courses comes within reach.

- **Higher level of engagement of youngsters in science, technology and maths, through novel educational software [–and opening up opportunities to access and use of laboratory equipment and virtual experiments–].** As mentioned in the beginning of this proposal, students tend to be motivated by
computer use in education. DEDUCATION will increase the opportunities of using computers in mathematics education significantly by providing a range of novel PRTEs developed based on feedback from hands-on experiences. Consequently, DEDUCATION has potential to increase the motivation levels in the mathematics classroom. The novelty of DEDUCATION’s PRTEs is based on TP-based software, which models the core of mathematical thinking technology, i.e. reasoning, and embodies mathematics knowledge down to first principles (LCF-style). Hence, DEDUCATION’s PRTEs are transparent for inquiry and self-explaining in their operations; using the PRTEs, nothing has to be taken for granted in mathematics anymore, everything can be challenged and scrutinized deep into the realm of higher mathematics.

- Faster, more timely and more cost-effective up/re-skilling through learning technologies and their sustained adoption by SMEs. A well educated workforce is a key factor for success in today’s rapidly changing business environments. Consequently, training in general, and self-training in particular, are getting more and more important for enterprises of all sizes. The project results of DEDUCATION will help enterprises to provide individual learning solutions, both in supervised (virtual) classroom scenarios as well as in self-teaching scenarios. DEDUCATION will develop solutions for teaching mathematics-related knowledge (which, e.g., in a business environment may appear in teaching advanced programming techniques or business analytics). Mathematical-related knowledge is traditionally taught in small and, thus, expensive classroom scenarios. Thus, DEDUCATION will on the one hand significantly reduce the training costs for enterprises, and on the other hand it will increase the number of employees that can take part in such trainings. Overall, the results of DEDUCATION will help European enterprise to stay ahead their competition in a changing and challenging business environment.

- Emergence of new learning models, including models invoking creativity. Traditionally, teaching and learning mathematics follows a sequence of (1) explaining concepts, (2) demonstrating problem solutions, and (3) solving exercises. Since feedback is generated automatically by TP-based software, DEDUCATION’s PRTEs make it possible to learn mathematics in a trial and error fashion, similar to learning chess with a good chess program: before the game is lost (if the solution gets stuck), back-track to a previous step and try another strategy. But where the chess program does not actually explain anything, the feedback provided by the PRTEs will be well designed in order to help students find their mistakes and overcome misconceptions.

3.2 Dissemination and/or exploitation of project results, and management of intellectual property

3.2.1 Exploitation

Exploitation Principles (Mission Statement). Exploitation is recognized as the key enabler for the success of the DEDUCATION project. Hence all partners of this intended project to be funded by the European Commission are aware of and committed to the exploitation of the project results. It is the principle of all exploitation activities to use research results to create value within all participating organizations and thus to improve their competitive advantages. Only by scaling up the results into the demonstration of technical options to political deciders in education policies on the one hand, and commercial offerings by classical editor houses in the school-book domain or more upstart SME’s offering services in this domain, our dissemination goals can be reached and thus profitable economies created.

Exploitation Approach. Wherever possible, research results will be exploited for the internal development as well as for the support of new products and services. The internal development — disseminated as open-source — should attract a community of researchers as well as companies (SME’s and beyond) that develop new solutions for a growing market. These products and services will lead to a competitive advantage of the participating organizations and will, last but not least, substantially contribute to the benefit of the targeted users: pupils and students. An integral part of this exploitation approach is the identification of
industrial strength use case scenarios which will serve as the validation point throughout the project and later. The majority of this task is attributed to WP5 for use case evaluations and WP6 for the other exploitation activities outlined below.

**Exploitation Activities.** The integrated exploitation approach of the DEDUCATION project will be accompanied by certain supportive activities, similar to the dissemination efforts described below:

- Transfer activities of research results into development, product, and service organizations, especially of the industrial partners.
- Continuous analysis of transfer opportunities, adjusting the project when necessary in order to ensure the best possible outcome.
- Investigation into the possible economic benefits and impact of the expected research results. Continuous evaluation of the advancement of the research results against the user requirements/needs throughout the project with the help of the use case partners, external advisors and adjustment of the project when necessary.

In the sequel, we detail the individual exploitation plans of the consortium partners.

**UPSud.** UPSud is represented in DEDUCATION by its competence in asynchronous proof processing and expertise to build formal methods tools in software engineering, be it the area of test case generation, verification, or other domains based on the processing of formal content. The main dissemination and exploitation channels for UPSud can be classified as follows:

- **Scientific Dissemination:** UPSud publishes scientific results in journals and as scientific conferences at suitable occasions, such as Journal of Automated Reasoning (JAR), Formal Methods (FM), Interactive Theorem Proving (ITP), and co-organizes educational events such as Thedu.
- **Code Dissemination:** Since key members of UPSud are also key developers of the Isabelle system and responsible for common interfaces and user interface technologies for Coq, it is possible that part of the DEDU-Framework and the DEDU-Web Framework become part of the Isabelle/Coq distribution, or entirely as “Isabelle-Server” distribution.
- **Internal training:** UPSud will evaluate the project in the context of internal training scenarios at the university level, in particular in the main classes on Advanced Software Engineering and Verification and Validation.
- **On a larger scale,** UPSud will take an active role in contacting and informing national deciders on education policies (such as http://eduscol.education.fr/dossier/manuel, first contacts have been established), schoolbook editor houses (Hachette) and private tutoring companies (e.g. Cours-Legendre, or a public institution: Centre National d’Enseignement à distance (CNED)). As dissemination form we plan to organize tutorials over the PRTEs, demonstrations of their used and the available content. In order to facilitate this task even for a more longterm perspective, UPSud engages to maintain and actualize the DEDUCATION Portal Server for more than 3 years after the end of the project.

**UdS.** The main exploitation and dissemination channel for UdS will be through the publication of scientific results in international journals and conferences, organization of scientific events and release of software and formal proof libraries under an open source license such as GPL or LGPL.

The UdS partner will aim at publications in the best journals and conferences specialized in both automated reasoning and the education.

The formal proofs and software prototype will be published online and submitted to repository of formal
proofs such as the Coq user contributions\textsuperscript{7} and the Isabelle Archive of Formal Proofs\textsuperscript{8}.

As Pascal Schreck is in charge of relation with high-school mathematics teachers we will also disseminate our results through this canal.

DFKI. With its specific set-up, DFKI will contribute prominently to both scientific dissemination and industrial exploitation.

The main dissemination channel for DFKI will be through the publication of scientific results in international journals and conferences, organization of scientific events and release of software under an open source license such as GPL or BSD-style. DFKI will aim to publish their results at the best journals and conferences specialized in computer mathematics, intelligent tutoring, technology enhanced learning and interactive and automated reasoning, such as the International Journal on Artificial Intelligence in Education (IJAIED), the Journal on Research and Practice in Technology Enhanced Learning (RPTEL), the Journal of Automated Reasoning (JAR) and the Journal on Mathematics in Computer Science, and the conferences Intelligent Computer Mathematics (CICM), Intelligent Tutoring Systems (ITS), Artificial Intelligence in Education (AIED), Interactive Theorem Proving (ITP) and International Joint Conference on Automated Reasoning (IJCAR).

The main industrial exploitation of project results by DFKI will be by supporting to move innovations as quickly as possible from the lab into the marketplace, which is an important element of DFKI’s mission. Only by maintaining research projects at the forefront of science such as DEDUCATION DFKI has the strength to meet its technology transfer goals. In particular, adequate user interfaces as developed in DEDUCATION for formal method tools as developed by DFKI are the key to the adaption of formal methods in industry; DEDUCATION will greatly enhance DFKI’s project acquisition capabilities with industry. Being anchored in the academic world, DFKI personnel engaged in university lectures will exploit the project results to teaching secure programming techniques and to prove mathematical properties of programmes and specifications of their environments.

SAP. SAP is the world’s leading provider of e-business software and a major industrial driver of service-oriented architectures. SAP applications are frequently used in security and safety critical applications. Government organizations use SAP’s public services offering, hospitals the eHealth solution and Supplier Relationship Management is employed for instance in a military context. In such critical environments, security is of utmost importance to protect the customer’s assets, such as systems, process execution and data. While the customer needs to access resources flexibly and dynamically over the Internet, a web application offering must not compromise security requirements or endanger the customer’s legal compliance. Moreover, it is common knowledge that a large portion of security problems (e.g., SQL injection vulnerabilities) are caused by insecure programming styles. Thus, techniques such as teaching analysis environments which ensure security of SAP applications are of particularly importance.

SAP is represented in DEDUCATION by its Security & Trust research practice and interested to evaluate the integrated DEDUCATION results for teaching and analyzing secure programming techniques. The Security & Trust research group developed strong company internal ties to the decision makers in the product organization, solution management and software architects alike, and serves as a trusted advisor in security topics.

The main dissemination and exploitation channels for SAP can be classified as follows:

- Internal training: SAP will evaluate the project in the context of internal training scenarios for SAP developers as well as experiment with applying the developed PRTEs in security audit scenarios.
- On a larger scale, the project results of DEDUCATION will influence SAP Secure Software Development Lifecycle and the SAP Product Security Standard.

\textsuperscript{7}http://coq.inria.fr/pylons/contribs/index
\textsuperscript{8}http://afp.sf.net/
• Scientific Dissemination: SAP Research publishes scientific results in journals and as scientific papers at suitable occasions, e.g., in conferences with appropriate objectives organized by ACM, IEEE, IFIP or with a European Union focus.
• Exploitation: SAP can play a key role in the uptake of the results and other exploitable by-products of DEDUCATION.

DEDUCATION will support SAP in providing secure applications for its customers. By addressing the security problems caused by programming errors, SAP expects to encounter fewer security vulnerabilities when using DEDUCATION results and therefore monetary savings due to reduced patch development.

JKU. The main exploitation and dissemination channel for JKU/RISC will be through the publication of scientific results in international journals and conferences, organization of scientific events and release of software under an open source license such as GPL.

JKU/RISC will aim at publications in the best journals and conferences specialized in computer mathematics, mathematics and computer science education, and/or automated reasoning such as the conferences hosted by the Conferences on Intelligent Computer Mathematics (CICM) series, Computer Science Education (CSE), Computer Theorem Proving Components for Educational Software (Thedu), Journal of Symbolic Computation (JSC), and others. Furthermore, the Softwarepark Hagenberg where RISC is located hosts a special communication branch of a high school which may be open to the use of the technologies developed in DEDUCATION.

UC. The main exploitation and dissemination channel for UC will be through the publication of scientific results in international journals and conferences, organization of scientific events and release of software and formal proof libraries under an open source license such as GPL or LGPL.

The UC partner will aim at publications in the best journals and conferences specialized in both automated reasoning and education, such as the conferences hosted by the Conferences on Intelligent Computer Mathematics (CICM) series, Computer Theorem Proving Components for Educational Software (Thedu), Computer Science Education (CSE), the IEEE International Conference on Advanced Learning Technologies (ICALT) the joint conferences Congresso IberoAmericano de Informática Educativa (IE: RIBIE/SIIE/TISE), the International Council for Educational Media (ICEM) and the journal such as the Journal of Automated Reasoning (JAR), Computers & Education, and others.

AAU. Results achieved at AAU in the context of DEDUCATION will be disseminated in publications in international journals and conferences targeting the subjects of computer supported mathematics, automated reasoning, as well as computer science and mathematics education. AAU will additionally make available online the educational material developed in DEDUCATION.

FMUBg. The main exploitation and dissemination channel for FMUBg will be through the publication of scientific results in international journals and conferences and release of software under an open source license such as GPL. FMUBg also plans to disseminate DEDUCATION results on annual national meetings of teachers of mathematics and informatics (organized by the Mathematical Society of Serbia).

3.2.2 Dissemination Plan

Dissemination Principles (Mission Statement) Dissemination is responsible for the communication on the project and its results, both to the internal audience, the scientific community and the potential business users of the outcomes of the DEDUCATION project. Hence all partners of this intended project to be funded by the European Commission are aware of and committed to a proper communication of the project results. It is the principle of all dissemination activities to use research results to create value within the targeted
communities of the European Union to ensure, government funding will lead to further advancements in securing the Future Internet, to ensure the viability of the web-based economy and keep business in the Future Internet landscape at the leading edge within the global market place.

**Dissemination Approach** Wherever possible, research results will be communicated for the external awareness creation and knowledge building within the targeted user and scientific communities of the European Union. The communication should guide and prepare potential users for the benefits and potential of the expected outcomes of the DEDUCATION project. In order for the dissemination to be effective, an integrated approach will be necessary, combining templates, guidelines and approval processes on one side with a communication platform, publication, event participation and release plans on the other.

The dissemination plan of the DEDUCATION project will be built upon seven important pillars: a central portal, communication, publications, events, training, community transfer and industrial transfer.

**DEDUCATION portal** The DEDUCATION portal (provided and hosted by UPSud) will make the results of DEDUCATION easily available to a wide audience. The portal will be created at the beginning of the project and will be regularly updated to reflect the actual state of the project. The portal will serve as a community building platform (including registration, event announcement and discussion opportunities), and will provide public access to white papers, publications and public deliverables of the project, such as reports and prototypes. The portal will be hosted within the .eu top-level domain, preferably under deducation.eu.

**Communication** The DEDUCATION consortium will create external visibility to the project towards various media. In particular, at the launch of the project, partners in each country will contact their national press agencies, and create direct visibility for the project and the European interest in this topic. The communication activities will be supported by all consortium partners (and their internal PR offices), and will be synchronized and coordinated by the project coordinator.

**Publications** The results of the DEDUCATION project will be disseminated by participating in international conferences and workshops about education and formal reasoning. The members of the consortium have a good track record in publishing in high-profile international journals and conferences, and intend to continue so. Scientific journals and major conferences in the areas of education and formal reasoning include:

- Conferences:
  - Interactive Theorem Prover (ITP)
  - European Symposium on Research in Computer Security (ESORICS)
  - Formal Methods (FM)
  - International Joint Conference on Automated Reasoning (IJCAR)
  - Automatic Deduction in Geometry (ADG)
  - Mathematical knowledge management (MKM)
  - User Interfaces for Theorem Provers (UITP)
  - Computer Algebra and Dynamic Geometry Systems in Mathematics Education (CAGME)
  - Conferences on Intelligent Computer Mathematics (CICM)
  - Conference on Certified Programs and Proofs (CPP)
  - Symposium on the Integration of Symbolic Computation and Mechanised Reasoning (Calculemus)
  - Computer Theorem Proving Components for Educational Software (THedu)
  - International Conference on Technology in Mathematics Teaching (ICTMT)
  - IEEE International Conference on Advanced Learning Technologies (ICALT)
  - Computer Science Education (CSE)
  - Intelligent Tutoring Systems (ITS)
  - Artificial Intelligence in Education (AIED)
– Computer Science Education (CSE)
– International Conference on Research and Education in Mathematics (ICREM)
– International Council for Educational Media (ICEM)

* Journals:*

– Journal of Automated Reasoning (JAR)
– Formal Aspects of Computing (FAC)
– Journal of Symbolic Computation (JSC)
– Journal on Artificial Intelligence in Education (IJAIED)
– Mathematics in Computer Science (MCS)
– Computers & Education
– Journal for Research in Mathematics Education
– Journal of Educational Computing Research
– Journal on Research and Practice in Technology Enhanced Learning (RPTEL),
– Journal on Artificial Intelligence in Education (IJAIED)
– Teaching Mathematics and its Applications
– International Journal for Mathematics Teaching and Learning
– Journal of Computers in Mathematics and Science Teaching

**Events.** One important dissemination channel of DEDUCATION are events with external stakeholders such as researchers, educationists, or publishers of teaching material. To ensure the timely dissemination of the project results, the project plans to organize at least three events targeting at the different stakeholders. At least one of those events will be a scientific workshop, co-located with a major conference.

**Training** The outcome of the DEDUCATION project will be disseminated and taught via various education and training activities – not only within the teaching activities of the project partners but, as well, addressing project external institution. Possible training activities include academic tutorials (organized in association with major conferences), summer schools (e.g. DEDUCATION-related lectures in established summer school by members of the consortium), as well as courses that explicitly target an industrial audience.

**Community transfer** The DEDUCATION consortium will closely work together with the several math teacher communities (such as Eduscol in France or the Department for Continuing Education for Teachers in Germany). In addition, DEDUCATION will also liaison with relevant EU initiatives, and foster research opportunities with other FP7 research projects in this area.

**Industrial transfer** There is a growing concern about the future of school books and the opportunities offered by e-books and tutorials. A key Exploitation objective of the project is disseminating information on prototypes PRTEs towards European publishers such as Hachette and Bertelsmann. We will organize demonstrations during events which will explicitly target publishers of educational material.
<table>
<thead>
<tr>
<th>Dissemination Item</th>
<th>Targeted Audience</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portal</td>
<td>General Public and specific teaching communities</td>
<td>1 for the project</td>
</tr>
<tr>
<td>Press releases</td>
<td>General Public and specific teaching community reviews</td>
<td>1 per prototype PRTE issued</td>
</tr>
<tr>
<td>Tutorial</td>
<td>Stakeholders: European and national policy makers in education such as:</td>
<td>1 per partner country</td>
</tr>
<tr>
<td></td>
<td><strong>France</strong> EDUSCOL</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Austria</strong> SCHULE.AT (leader is Markus Hohenwarter, an associated partner):</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Germany</strong> Department for Continuing Education for Teachers (Amt für Lehrerfortbildung)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Portugal</strong> Portuguese Mathematical Society (Sociedade Portuguesa de Matemática)</td>
<td></td>
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<tr>
<td></td>
<td><strong>Serbia</strong> Mathematical Society of Serbia (Društvo matematičara Srbije)</td>
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<tr>
<td></td>
<td><strong>European Commission</strong> Portal eLearningeuropa.info. An initiative of the european commission aiming to transform education through technology.</td>
<td></td>
</tr>
<tr>
<td>Demonstration during Events</td>
<td>Teacher and Professionals such as private publishers</td>
<td>2 for the project</td>
</tr>
<tr>
<td>Organization of workshop</td>
<td>Education community</td>
<td>1 for the project</td>
</tr>
<tr>
<td>Publications</td>
<td>Researchers</td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.3 IPR Management

The IPR resulting from this projects will be used along the following Principles:

1. The core components of DEDUCATION (WP1, WP2) will be put under an open-source license that is compatible with Isabelle and Coq — i.e. under Berkeley Licence, to be precise.

2. With respect to the implementation of the PRTEs, we will decide on an individual basis, which PRTE will be open-source and which will not (for the academic partners, this will be the default, for the industrial partner, we will try). Details will be worked out in the consortium agreement.

3. With respect to the content of the PRTEs, what will be open-source and which will not (for the academic partners, Creative Common By-license will be the default, for the industrial partner, we will try) . Details will be worked out in the consortium agreement.

**IPR Management during the project**

For the success of the DEDUCATION project it is essential that all project partners agree on explicit rules concerning IP ownership, access rights to any Background and Foreground IP for the execution of the project and the protection of intellectual property rights (IPRs) and confidential information before the project starts. Therefore, such issues will be addressed in detail within the Consortium Agreement between all project partners. The main purpose of the Consortium Agreement is to establish a legal framework for
the project in order to minimize any internal issues within the DEDUCATION consortium related to the work, IP-Ownership, Access Rights to Background and Foreground IP for the duration of the project and any other matters of the consortium’s interest.

**Access Rights to Background and Foreground IP during the project**
In order to ensure a smooth execution of the project, the project partners agree to grant royalty-free access to Background and Foreground IP for the execution of the project. Therefore, all project partners determine any Background IP they are willing to submit to the project within the Consortium Agreement before the project starts. Any details concerning the access rights to Background and Foreground IP for the duration of the project will be defined in the Consortium Agreement.

**IP Ownership**
Foreground IP shall be owned by the project partner carrying out the work leading to such Foreground IP. If any Foreground IP is created jointly by at least two project partners and it is not possible to distinguish between the contribution of each of the project partners, such work will be jointly owned by the contributing project partners. The same shall apply if, in the course of carrying out work on the project, an invention is made having two or more contributing parties contributing to it, and it is not possible to separate the individual contributions. Any such joint inventions and all related patent applications and patents shall be jointly owned by the contributing parties. Any details concerning the exposure to jointly owned Foreground IP, joint inventions and joint patent applications will be addressed in the Consortium Agreement.

**Consortium Agreement**
The purpose of the Consortium Agreement is to establish a legal framework for the project in order to minimize any internal issues within the DEDUCATION consortium related to the work, IP-Ownership, Confidential Information, Access Rights to Background and Foreground IP for the duration of the project and any other matters of the consortium’s interest.
4 Ethical Issues

<table>
<thead>
<tr>
<th>Informed Consent</th>
<th>YES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the proposal involve children?</td>
<td></td>
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<tr>
<td>Does the proposal involve patients or persons not able to give consent?</td>
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<tr>
<td>Does the proposal involve adult healthy volunteers?</td>
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<tr>
<td>Does the proposal involve Human Genetic Material?</td>
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<tr>
<td>Does the proposal involve Human biological samples?</td>
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<td></td>
</tr>
<tr>
<td>Does the proposal involve Human data collection?</td>
<td>X</td>
<td>55</td>
</tr>
</tbody>
</table>

Research on Human embryo/foetus

| Does the proposal involve Human Embryos? |     |      |
| Does the proposal involve Human Foetal Tissue / Cells? |     |      |
| Does the proposal involve Human Embryonic Stem Cells? |     |      |

Privacy

| Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction) |     |      |
| Does the proposal involve tracking the location or observation of people? |     |      |

Research on Animals

| Does the proposal involve research on animals? |     |      |
| Are those animals transgenic small laboratory animals? |     |      |
| Are those animals transgenic farm animals? |     |      |
| Are those animals cloned farm animals? |     |      |
| Are those animals non-human primates? |     |      |

Research Involving Developing Countries

| Use of local resources (genetic, animal, plant etc) |     |      |
| Impact on local community |     |      |

Dual Use

| Research having direct military application |     |      |
| Research having the potential for terrorist abuse |     |      |

ICT Implants

| Does the proposal involve clinical trials of ICT implants? |     |      |

4.1 Handling of Ethical Issues Related to Human Data Collection in DEDUCATION

The computer supported learning and teaching environments that are built in the project will be studied in empirical field trials. This is done in the form of classroom teaching in high schools and universities. Information about how students use these environments will be collected during the trials, both automatically and by tests and questionnaires, in order to be able to evaluate the performance of these tools. The specific information that is collected will be explicitly stated before the trials, and has to be approved by the educational authorities involved. The educational authorities will get the approval by parents, if they think that this is needed. All information will be treated confidentially and anonymously.
References


