Evaluation and impact framework

Managing the impact framework: The progress and impact of the center will be monitored by the Center leadership and the Center board (action A0.7 in the action plan). An impact evaluation group (IEG) consisting of representatives from the center, the university leadership, teachers, students, stakeholders, and international educational researchers will review the progress yearly (A0.3), report on the results and impact (A0.4), and provide directions for development and improvement. Minor deviations will be addressed by the Center, whereas larger deviations will be reported. Based on results, funding may be realigned to optimize value for money.

Monitoring progress: We will develop measures of progress based on milestones and deliverables in the activity plan and in the ten-year goals, and measures to evaluate the development (i) in quality indicators at the individual, course/program and institutional level; (ii) in recruitment, retention and graduation rates; and (iii) in students scores on standardized and customized tests. The milestones and deliverables in the action plan lay out a path to ensure we reach the five and ten year goals. We will use quantitative and qualitative methods to monitor the progress in the work packages using indicators for input, process and outcome[1,2] and compare it to the initial baseline for the center, to non-CSE cohorts, and to the target results from milestones and five- and ten-year goals. Quantitative input and outcome measures of progress according to milestones provide a first order control. For example, we will record the number of: web repository uploads (A1.1); textbooks (A1.2); writer meetings (A1.4); data-based examples (A2.1); assessment studies (A2.3); study programs changed (A2.5); mentor programs and teacher retreats (A3.2, A3.3); student researchers (A4.7); faculty workshops (A5.1); and courses with CSE integration (A5.2). Indicators of progress will be assembled for *all* elements in the action plan (not only the examples listed above), combined with qualitative observations of process and outcome indicators, and addressed by the evaluation group (IEG, A0.3).

Measuring impact on learning: There are research-based methods that combine interviews, surveys and tests to characterize students' qualitative and quantitative understanding in physics and other fields[3–6], their degree of expert thinking[7,8], their motivation[9,10], and their creativity and critical thinking[11] to name a few. We will apply such measures as indicators of students' learning in their field to evaluate the effectiveness of the materials, methods and approaches introduced (e.g. in A1.2, A2.2, A3.1, A4.2, A5.2). However, the center aims to develop new materials and methods for a new curriculum that integrates computing. Therefore, new methods to evaluate student learning outcomes of CSE concepts will be developed, tested, refined and distributed internationally as standardized test kits. Thus the need to establish a CSE educational research activity with senior researchers, post-docs, and PhD-students to lead the development and application of such tools. The progress on these indicators will also be reported to the evaluation group (IEG, A0.3) and will serve as benchmarks for dissemination and the application of CSE at other institutions and in other fields. The center will address results and experiences of various sub-groups of students[12] in terms of gender, ethnicity, and motivational patterns, and take measures to develop an equitable learning environment and effective learning approaches for all students.

Measuring culture change and impact of dissemination: The CCSE aims to change the teaching and learning culture. Progress will be characterized by indirect studies, such as the number of activities directed towards culture development (e.g. retreats), and direct studies using interviews, observations and surveys of teachers and students to address satisfaction, attitudes, motivation, and values, as well as studies of stakeholder and leadership perspectives on the development.

Deep impact: Interviews, observations and surveys will be used to address how CCSE impacts study program design across fields, institutions' attitude toward computing proficiency. Government and stakeholder perspectives will be addressed by a stakeholder panel with industry representation.

Consolidating adaptation: Physics education research[13–16] show that even if the evidence for student-active teaching methods is known among teachers, the methods are scarcely applied and often quickly discontinued if applied. Thus we need to go beyond dissemination to inform to ensure long-term adaptation of CSE methods. We will therefore monitor retention by interviewing key influential faculty, address all faculty through questionnaires based on the interviews, measure effects of dissemination and the long-term use of CSE methods, and use the results to adapt our approach to consolidate adaptation. These studies will be done in collaboration with the PICUP project[17] and Prof. Caballero at MSU, who will be an adjunct professor at CCSE.

Unique learning analytics: One post-doc will apply big data analysis of learning analytics data to map out what methods and activities are most effective. We have unique access to assessment data since we use a student-developed delivery system for compulsory exercises (*devilry.org*), which allows teachers to correct and categorize mistakes according to standard misconceptions. Combined with the transition to digital exams, the use of classroom response systems, and data from student-developed learning apps, this will provide extensive data on learning outcomes and its relation to instruction, feedback and class participation. Insights will be used to optimize teaching methods.

Student-driven evaluation: Students will participate actively in evaluation and research (A4.2). Student teams will interview students and conduct surveys on learning experience and outcome - expanding a practice we have developed through the ReleQuant project[18]. Students will do in-class observation of active learning and problem-solving sessions and report using standardized forms[19], providing insights into the use of learning materials and problem-solving processes. Students will evaluate texts and other learning material using the web repository's feedback functions. Participation in research and evaluation projects give students valuable learning experiences as well as a meta-perspective on their own learning processes.

Dissemination, dialogue and communication through partnerships

Research-based dissemination: Physics education research have rigorously documented the effect of student-active teaching methods, yet these methods are sparsely used[15]. This has motived researchers to develop a research-based approach to dissemination that takes into account the many complexities of educational change[13,14,16]. Our dissemination strategy builds on these research-based recommendations and will provide easily modifiable materials; disseminate research ideas in addition to curriculum since users often modify methods; adapt approaches to realistic situational constraints; and involve faculty as partners and provide support. CCSE will develop modular learning materials that can be combined with existing materials to suit local constraints. We will not only inform, but also provide follow-up instruction through workshops and individualized instruction, monitor dissemination results, and adapt approaches accordingly (A0.5). Finally, successful integration of CSE requires constructive alignment between leadership, faculty, students and stakeholders - hence our dissemination strategy must address all these groups in concert.

Learning material: New curricula require new learning materials. The center will establish an interactive web-based repository for teaching methods, lectures, exercises and exams that includes experiences and feedback from practitioners, students, and stakeholders. An international textbook series will be published through a partnership with Springer. The center will host doconce[20], a tool to modularize and publish texts across platforms with interactive code and visualization.

Research results: The effect of new material and approaches on learning outcomes must be documented to gain acceptance and to convince students, faculty and leadership to adapt CSE. Research results will be published internationally, presented at conferences by students and faculty, presented to university, government officials and industry by faculty and leadership, and popularized for general media and blogs by students, faculty, and leaders. Experiences, results and methods will be presented at *a yearly national CSE conference* that will include systematic training of university teachers following the research-based recommendations.

Internal dissemination: The center will host regular research seminars, seminars on educational practices, CSE workshops and yearly teacher and student retreats to educate leadership, teaching faculty and students and to build a culture for teaching and learning. The center will support teacher and student development projects to initiate and develop approaches in new fields, and establish scholarships for students to work on educational development or research projects.

Extensions beyond physics: While CCSE starts from the physics education, our goal is to successfully disseminate methods and approaches across fields. However, dissemination must be adapted to the situational constraints of particular fields and institutions. Therefore, we will form partnerships with key players from various fields and institution types to develop a broad range of methods and approaches that can be adapted to specific needs.

Extension at UiO - biology: The extension to biology (A5.2) demonstrates how to integrate computing in less mathematical fields. Dissemination will be organized as partnerships, where leadership, faculty and students align through the following steps: (i) Develop study program with leadership, senior faculty and students. (ii) Interdisciplinary teams of PhD students and faculty develop new textbooks, materials and approaches. (iii) Pilot courses are tested on biology students, evaluated and adjusted before entering the regular curriculum. (iv) Continuously investigate and adjust approaches, and evaluate and review course and program progress with leadership. We will provide workshops, individualized instruction, and scholarships for summer students for teachers who want to start integrating computing in their courses. The CSE research group will develop and apply evaluation methods to study changes in student learning through the introduction of CSE.

Extension at UiO - other fields: Insights from integration in physics, with high math integration, and biology, with low math integration, will be used in dissemination in other fields. Extensions to astronomy, chemistry, geoscience and meteorology has strong leadership support, is already planned and to some degree initiated (A5.2), and CSE is integrated into the learning outcomes of study programs and in some courses. Implementation will follow strategies similar to that in biology and physics. Further science programs and other fields will gradually be added.

National dissemination: We will inform and influence stakeholders, including government, through conferences, students, leadership meetings, professional networks and a general media strategy. Extension to other universities will be based on adaptations of textbooks, material and approaches (A5.3) and supported by workshops with individual instruction. Extension to other types of institutions will be piloted in a general engineering program at the University College of Southeast Norway (A5.3). In the pilot, we will revise learning outcomes to include programming; adapt and evaluate materials and approaches from UiO; develop new courses and material, including textbooks; and disseminate through students, leadership and professional networks.

International dissemination will occur through international research publications, conferences, professional networks and textbook series. Extensions will be developed with key international collaborators such as Michigan State University and the PICUP[17] project, and through collaborators from our international platform for educational and research partnerships, INTPART[21].

School partnerships: The introduction of CSE may lead to new challenges for students as they transition from schools to university. We will therefore study the transition process in partnership with selected schools where school classes visit the university to work on a realistic, research-near project that integrates mathematics, computing, and physics.

Student-driven dissemination: Students can be powerful agents of change. We will partner with students so that they can argue for the integration of CSE in new programs in student forums and conferences nationally and internationally - helping the students shape their own future.

Sustainability

Exit strategy: The resources invested during the center period will result in a well functioning CSE educational research activity, a long-lasting culture for teaching and learning, a sustainable CSE infrastructure, a strong CSE brand, and many students educated for tomorrows challenges.

CSE educational research group: After the center period the senior researcher position in the center will be extended into two permanent associate professor positions, which will be financed by the Department of Physics, to ensure that the CSE educational research activity will continue and that educational research and teaching will be closely integrated. The research group will gradually build up its portfolio of external projects and grants from the Norwegian Research Council, the EU framework programme, and other sources of financing, in order for the group to be self-financed at the end of the center period. The group will aim to lead EU financed educational research projects to build an international CSE platform. The CSE educational research group will continue to serve as a hub for science education research at the Faculty of Mathematics and Natural Sciences in close collaboration with the Academic Development Group at the Department for Education.

Institutional changes: CSE is and will be an integral part of the Faculty of Mathematical and Natural Sciences' and the Departments' educational strategies. CSE will be integrated in study program design and learning outcomes, curricula, and teaching practices beyond the center period. Traditions for teaching excellence will be embedded in lasting practices such as pedagogical courses, seminars, academic hiring, and a part of the student and teacher culture. CSE will be a part of the educational strategy of the Faculty and the relevant institutes at UiO, and a central brand name for the university. A CSE module will be provided for the compulsory university teacher educational programme. The culture for teaching and learning will be supported by annual CSE conferences also after the center period. Student programs, such as the use of summer students for teaching and learning innovations in courses, will be continued at a lower funding level, financed by the Faculty. The quality control system at the Faculty for Mathematics and Natural Sciences will have shifted from quality control to quality improvement, allowing for more constructive student evaluations. Student evaluations of individual courses will occur through end-of-semester focus groups using a web-based form where questions about CSE integration will be included.

Infrastructure for CSE: The textbook series, web repository, assessment and cross-platform text publication systems will be developed and hosted by UiO also post center.

Students for the future: The most important product from the center that will have lasting impact on Norwegian and international research and development are the students educated. With a solid foundation in their respective fields, computational proficiency and experience from cross-disciplinary research projects they will have the motivation, creativity and skills needed for tomorrows workplace.

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