Evaluation of Mathematics, ICT and Technology (EVALMIT) 2023–2024

Self-assessment for research groups

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Institution (name and short name): Norwegian University of Science & Technology (NTNU)
Administrative unit (name and short name): Department of Computer Science (IDI)
Research group (name and short name): Software Engineering and Learning Technology (SE-LT)
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1. Organisation and strategy

1.1 Research group's organisation

The Software Engineering (SE) and Learning Technology (LT) research group was established in 1985 by prof. Conradi. In June 2023, the group had a staff of 31 persons: 10 permanent (6 prof., 4 assoc. prof.) and 21 temporary staff (4 postdocs, 3 adjunct assoc. prof. and 14 PhD candidates). Initially, the research focus was on the planning, development and operation of complex software products and topics that are crucial to the software industry and society as a whole. From 1995 onwards, the group focused on empirical SE; from 2014, the group gradually developed a research strand on LT as prof. Wang shaped a very successful new research profile from SE to LT research and prof. Giannakos was hired. The LT strand addresses the design, evolution and implementation of learning technologies, with a focus on game-based learning, learning analytics and multimodal data. Today, six of the permanent staff work in the SE strand and four in the LT strand, with the foci on empirical studies and research on design and development of software uniting the group. The group maintains several entities to support its research foci, in particular the Norwegian GEMINI Center for Software Engineering (NSE), the Software for a Better Society lab (SBS lab) and the Learner–Computer Interaction lab (LCI lab). The role of these entities is to nurture research proposals and high-quality publications in SE and LT, recruitment, and supporting MSc and PhD supervision.

Each PhD candidate has a main supervisor and one or two co-supervisors. Each PhD candidate enrols in the PhD study programme in CS. The supervisory team, doctoral-level courses and research plan are approved by the faculty. The section organises dedicated courses for PhD candidates with a focus on SE and LT research and academic writing. All PhDs are also encouraged to participate in top-tier summer schools and doctoral consortia in SE and LT communities. At midterm, PhD candidates go through a formal evaluation that gives input to the candidate and the supervisory team. The NSE holds annual seminars to introduce temporary faculty to researchers at SINTEF and the University of Oslo. The NSE has also organised talks about publishing in journals and to tracks at top SE conferences. PhDs working in LT are invited to monthly seminars on LT research and are trained to use advanced equipment such as multimodal and sensing equipment (e.g., eye-tracking, EEG and physiological equipment). Moreover, LT PhDs attend annual research meetings such as the Nordic Learning Analytics Summer Institute (LASI) and the Multimodal Learning Analytics Across Spaces (Cross-MMLA) series.

The group encourages faculty members to make use of their research terms abroad. In recent years, SE-LT faculty have conducted research stays at UCL, CMU, the University of Melbourne, EPFL, TU Eindhoven, the University of Pisa and Peking University. Every PhD candidate is highly encouraged to undertake a research stay abroad for one semester. The candidate prepares a proposal with their supervisor, and the department approves and funds it. Our recent PhD students have conducted research stays at UC Berkeley, the University of Melbourne, EPFL, Aarhus University and Nanjing University. Our group has also received mobility grants from the NFR and HK-dir for collaboration with the US, China and Brazil, as well as from foundations (notably the Peder Saether Center for Advanced Study that covers mobility between our group and UC Berkeley). Our group has also been very successful in relation to international mobility programmes. We have recently hosted researchers funded by ERCIM, EU COST Action, Swiss-NSF, Erasmus+ and the Marie Skłodowska-Curie Actions (MSCA), and some of our professors hold visiting professorships (TU Eindhoven, Peking University), honorary professorships (UCL) and adjunct research positions (SimulaMet, Visma).

The research is mostly organised around portfolios of projects that are funded externally. Core funding is used to cover faculty members' research time, and PhDs and postdocs are funded either by external funds or by fellowships provided by the department or the faculty. The quality of SE-LT's research is on par with the relevant leading groups in Europe, with large number of publications in the premier SE-LT venues, faculty members featuring as highly cited (e.g., Stanford's list), more than 100 MNOK of competitive research funding during the last 5 years, and several distinctions, innovations and awards.

Table 1. Number of personnel by category.

Category of personnel	No. of personnel	Proportion of women	No. of researchers who are part of multiple (other) research groups	No. of temporary positions
Professor	6	33.3%	0	0
Associate Professor	4	25%	0	0
Postdoctoral Researcher	4	100%	0	4
PhD Candidate	14	50%	0	14
Adjunct Professor	3	0%	0	3

1.2 Research group's strategy

a) Main goals, objectives and strategies

The group is a national leader and an internationally renowned hub of excellence in SE and LT research. It focuses on two research directions. First, it addresses the development and understanding of complex IT systems from an SE perspective and contributes to providing novel research results on topics of importance to the software industry and the public sector. Second, it addresses the design, development and use of technologies to support human learning. We use a blend of large-scale and small-scale empirical research methods to study how to design and use software, ranging from analytics, data mining and user modelling, to ethnographic, case study and field observation methods.

Our goal is to maintain and further expand our position as a world-class research group in SE and LT. Accordingly, we focus our resources around four main objectives. First, our research is funded by several national and international projects, including highly competitive schemes from the Norwegian Research Council (NFR) and the European Commission (EC); our objective is to maintain and further scale up our project portfolio by developing successful applications for long-term funding and even higher prestige (e.g., ERC and SFF). Second, our work publishes in the premier SE and LT conferences and journals; our objective is to further concentrate our resources on those top-tier venues, doubling our presence in the next five years. Third, our group maintains a long record of innovative systems that have received awards and recognitions from both the premier research venues (e.g., awards at top conferences: LAK '18, CSCL '21, EC-TEL '18 and '19) and the respective industry platforms (e.g., Kahoot! with more than 100 million monthly users); our objective is to maintain this leading position by capitalising on our experience and network, further increasing the number of innovative systems. Fourth, most of the faculty members of our group participate in senior editorial (e.g., *IEEE TLT*, *IEEE Software*, *BJET*) and organisational roles (e.g., general and PC chairs for IDC, AVI, EASE, FSE); our objective is to increase our involvement and leadership in world-leading networks by organising venues such as ICSE, ESEM, LAK and FSE (we have already hosted IDC'18, ITiCSE'20, EASE'20, and agreed to host FSE'25). Our overarching objective is to further position our group as a beacon of excellence in both SE and LT.

To achieve these objectives, we have developed a support system for faculty members who are working towards top-tier research grants and publications. Faculty members working on competitive funding calls or publications receive support from faculty members with previous experience and a track record in the area. This allows faculty members who have less experience to develop the necessary competence. Another strategy involves leading the national collaboration with the software industry and public sector, where we work closely with the SINTEF research foundation and the University of Oslo in the NSE. Furthermore, we seek to strengthen that collaboration beyond the NSE through adjunct positions, with prof. Dingsøyr currently an adjunct chief scientist at SimulaMet and prof. Cruzes a lead security researcher at Visma.

b) The benchmarks of the research group

The department strategy from 2018 to 2025 prioritises the research areas of "development and understanding of complex IT systems from a software engineering perspective" and "technologies that support learning (including 'serious gaming' and 'learning analytics')". The ambition is to conduct high-quality research in line with internationally acknowledged criteria that is highly relevant to the public sector and to business. We have, in collaboration with the department, defined the following benchmarks for SE and LT:

1) Publish in and play a central role at the premier SE[1] and LT[2] conferences and journals.
2) Further develop a strong portfolio of competitive national and international projects in both SE and LT, and be the preferred SE/LT Norwegian partner for attracting funds from competitive national (NFR) and international (EU) funding agencies. (each faculty member is a PI on at least one competitive national or international project)
3) Conduct research that is relevant and has an impact on society and the IT industry.
4) Foreground research-based SE education with technological innovations and novel pedagogical interventions.

The overarching benchmark is that our group will maintain an international research profile in SE and LT; we position ourselves as a leading European group that focuses on SE and LT research. Therefore, our profile should be comparable with that of other leading European groups with a similar focus from prestigious universities. In particular, we compare ourselves to and collaborate regularly with 1) the SE groups of the IT University of Copenhagen and Blekinge Institute of Technology, and 2) the LT groups of KTH (TEL group), EPFL (CHILI group), the University of Copenhagen (CDE) and Aalto (LeTech group).

c) The research group's contribution to education (Masters degrees and/or PhDs)

We provide graduate and undergraduate courses in SE and LT. At graduate level, we are responsible for the "software systems" specialisation, while for the "Interaction design, gaming and learning technology" specialisation, we are responsible for the courses related to learning and game technologies. At undergraduate level, we provide research-based education in courses such as SE, software architecture and software security, which are taken by around 500, 400 and 300 students respectively every year.

At graduate level, the group has a 50-year history of project-based education in collaboration with the industry. For example, the "Customer driven project" course (a capstone SE course) has led to eight publications in leading SE venues and has an active network of more than 75 organisations in Norway (see a recent *IEEE Software* paper). Moreover, the group maintains an active participation in the CS education community and regularly publishes its teaching innovations to the most prestigious venues such as ITiCSE, ICER, TOCE, and the ICSE Software Engineering Education and Training track. Further evidence of our group's teaching quality is provided by the regular distinctions we receive (e.g., prof. Wang is one of the 34 NTNU teachers who has received a distinguished teacher status; prof. Giannakos received funding from the NTNU' Teaching Excellence program; and Associate Professor Papavlasopoulou received an AIS Education Award at ICIS 2022).

We supervise a large number of master's thesis projects (about five per faculty member per year), related to SE with a focus on large-scale industry contexts, and to LT with a focus on learning analytics and game-based learning. Several theses have resulted in top-tier publications (e.g., in *JSS*; at IFIP Interact, CSCL, and LAK), distinctions (e.g., the Norwegian Computer Center award in 2019) and the development of innovative companies (Kahoot!; PlayPulse; BitPet)

[1] **Journals**: *IEEE Transactions on Software Engineering (TSE)*, *ACM Transactions on Software Engineering and Methodology (TOSEM)*, *Empirical Software Engineering (EMSE)*, *Information and Software Technology (IST)*, *Journal of Systems and Software (JSS)*, *IEEE Software*. **Conferences**: International Conference on Software Engineering (ICSE), ACM/IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM), International Conference on Evaluation and Assessment in Software Engineering (EASE).

[2] **Journals:** *Computers & Education (C&E)*, *British Journal of Educational Technology (BJET)*, *International Journal of Computer-Supported Collaborative Learning (IJCSCL)*, *IEEE Transactions on Learning Technologies (IEEE TLT)*, *Journal of Computer Assisted Learning (JCAL)*, *Computers in Human Behaviour (CHB)*, *Journal of Learning Analytics (JLA)*. **Conferences:** Learning Analytics and Knowledge (LAK), ACM Interaction Design and Children (IDC), Computer Supported Collaborative Learning (CSCL).

Doctoral studies at IDI (the PhD in CS) are centrally managed. However, our group offers PhD-level courses, seminars and masterclasses relevant to our research background and contributes to international schools, courses and tutorials. Graduate PhDs from our group have secured academic positions in Norway and abroad, as well as top R&D positions (e.g., at Equinor and SINTEF). Overall, we contribute to education at both the Masters and PhD levels in topics that are relevant to SE, LT and gaming technology. Our approaches often receive recognition for teaching excellence, and PhD work is published in high-ranked conferences and journals.

d) The support the host institution provides to the research group

The host institution provides important technical support to the group. In particular, the host has a dedicated IT section that supports us with setting up servers and VMs when needed, as well as assisting us with the use of the Maker and UX lab. Moreover, the IT section provides internal research and training for our master's degree and PhD candidates (e.g., how to use eye-tracking or 3D printing technology). In terms of administrative support, the department's HR professionals and economists assist us with hiring personnel and preparing national project budgets. For international project budgets, assistance is provided by the central economy section at NTNU and by EU advisors at the faculty level. The group has no direct access to any institutional budget, but it can request resources from the strategy budget at the section level, which is used to fund conference travel and small items of equipment.

1.3 Research group's relevance to the institutions

Research on SE in relation to large IT systems and agile methods is directly relevant for the university in projects where, for example, new self-service solutions are developed. Furthermore, studies on LT have a direct impact on teaching methods and teaching quality. Several technological innovations have been developed with the goal of addressing institutional strategies. For example, one of the objectives of the design and development of Lecture Quiz! (later renamed Kahoot!) was to support teachers of large courses (i.e., courses with several hundred students) to interact with their students during lectures. In another example, the Adapt-IT programme allowed thousands of NTNU IT students to self-assess their skills and receive adaptive support via learning analytics. One last example is the development of the Learn2Analyze MOOC, which allowed students and instructors to develop competencies connected to the use of educational data and learning analytics.

Both the faculty and the department have a strategy from 2018 that focuses on making digitalisation sustainable and ethical, with clear objectives on addressing inclusion and gender equality. Our group makes clear contributions to the digitalisation of Norwegian society by implementing studies on SE with both industry (e.g., Equinor, Kantega, DNV) and the public sector (e.g., Lånekassen, the Norwegian Welfare Administration, municipalities), and we have conducted field research with more than 50 Norwegian companies. Moreover, our group has led several initiatives in empowering gender balance in IT, for example by chairing the EU EUGAIN network coordinating the IDUN project, having chair roles at the ACM womENcourage conference (and hosting its 2023 edition) and participating in several relevant projects (e.g., Women STEM UP).

Another important contribution by the group to institutional strategies and objectives is its coordination of large EU projects, reaching the final stage of the ERC (twice), developing world-class innovative technologies (e.g., Kahoot!) and leading the national dialogue on the digitalisation of education by participating in ministerial committees (e.g., for the implementation of Learning Analytics in Norway). Due to these activities, members from our group (Giannakos) were invited to join NTNU's Outstanding Academic Fellows program, which is one of NTNU's strategic mechanisms for achieving research excellence. All these actions address important objectives for the IDI's strategy, which thus has a clear focus on SE and LT as well as on SE/CS education. In relation to SE education, the group has produced a steady stream of publications with a focus on project courses and data collection from

large courses. The department also gives priority to the topic of information security, where the group has made key contributions to continuous software security work.

1.4 Research group's resources

Table 2 shows that our resources come primarily from NFR and international funding (usually via EU frameworks). The portfolios of projects mainly fund the PhD and postdoctoral fellowships we offer. This is complemented by NTNU-level funding (included in Table 2 under "Other") that usually accounts for PhD and postdoc fellowships, as well as smaller internal grants that the group obtains through internal competition (e.g., open calls, or matching funds if we secure large EU/NFR projects). The "Basic funding" category describes the cost of the research time of the permanent faculty members, and we also recruit a smaller amount of funds from other national resources (e.g., DIKU and NORAD).

Overall, our funding profile is balanced between national and international funding, which reflects our goal of playing a central role nationally while maintaining an internationally competitive profile. The projects funded by NFR (e.g., IKTPLUSS, Young Research Talents) and the projects funded by EU frameworks (e.g., Horizon 2020, Horizon Europe, MSCA) and NordForsk are all very competitive in nature, with a clear focus on funding PhD and postdoctoral fellowships, as well as on participating and leading project consortia that are at the forefront of SE and LT research. Funding from industry and the private sector appears limited in comparison; however, this is due to the form that such collaborations take, such as in-kind funding from industry participants and direct hiring of PhDs or postdocs. The funding for 2023, as well as the ongoing high-quality applications for funding indicate a further stable growth in our group. In summary, we plan to maintain this balance between national and international funding and focus on highly competitive projects that primarily fund fundamental research via PhD and postdoc fellowships. At the same time, one of the main objectives for the next five years is to secure longer-term funding (with a horizon of five to ten years, instead of three to four years) from even more prestigious calls (ERC, SFF) that will allow us to pursue even more ambitious projects that could lead to major scientific breakthroughs.

Table 2. Sources of R&D funding (NOK) for the research group, 2018–2022.

	2018 (NOK)	2019 (NOK)	2020 (NOK)	2021 (NOK)	2022 (NOK)
Basic funding	2,328,800	2,328,800	2,328,800	3,635,200	4,998,400
Funding from industry and other private sector sources	340,000	340,000	340,000	0	0
Commissioned research for the public sector	0	0	0	0	0
Research Council of Norway (NFR)	3,930,952	6,305,952	7,964,702	8,582,667	7,916,000
Grant funding from other national sources	902,500	902,500	902,500	0	0
International funding (e.g., NIH, NSF, EU framework programmes)	5,180,167	4,790,167	5,758,667	6,320,667	8,464,132
Other	4,047,000	8,697,500	8,165,000	9,407,500	10,472,500

1.5 Research group's infrastructures

a) National infrastructures managed or co-managed by the group

It is important to clarify that the most important infrastructures for the SE group are not tangible, but rather established networks with the software industry. This is because most research in both SE and LT is conducted in situ or with the industry as our laboratory, which makes access to those resources and networks crucial for our activities. Our group has either developed or co-manages several such

resources. First, the orchestration and management of the software industry resources happens through the NSE (initiated by prof. Dingsøyr and prof. Jaccheri) and the Customer Driven Project, a capstone project course where our MSc students develop a software product with a customer drawn from a network of more than 75 organisations. Another important infrastructure our group has developed and uses is the JoinGame network. JoinGame is a national network focusing on strengthening the Norwegian computer game industry through skills development and by intensifying collaboration with Norwegian and international game research. The network was initiated and chaired by prof. Wang and has over 500 members from more than 200 organisations in Norway. Although JoinGame funding (from the NFR) ended in 2015, the connections and resources of the network remain an asset for our group and our position as a national leader in game development research. Other valuable resources our group co-manages and contributes to are the International Software Engineering Research Network (ISERN), SoLAR's SIG in multimodal learning analytics (Cross-MMLA) and the Nordic Learning Analytics Institute (LASI-Nordic). Those resources help us not only to conduct large-scale research studies to high academic standards, but also to maintain our relationships with top-tier national and international institutions for initiating collaborations and exchanging equipment (e.g., via LASI-Nordic), and for training new PhDs and postdocs (e.g., via the GEMINI Center and Cross-MMLA). We maintain those resources via common external funding applications, mutually beneficial collaboration and annual gatherings with a focus on strategy and competence development (e.g., data analysis training and courses on scientific publication).

b) The most important research infrastructures used by the group

The group maintains a healthy balance between lab studies and studies taking place in situ. It shares a UX lab and a Maker lab with the information systems group; these labs allow us to conduct usability and user experience studies, as well as to prototype the parts needed (e.g., for wearable tech or exergames). Moreover, the LT members of the group are organised around the LCI lab, and LCI has state-of-the-art equipment for prototyping, user testing, and advanced sensing and wearable technology. In particular, the LCI lab provides motion- and eye-tracking facilities, and the equipment and infrastructure that are needed to come up with multimodal user interfaces (e.g., hardware set-ups that turn any room into an interactive space). Advanced sensing devices are also provided to support experimentation and data analysis (e.g., eye-trackers, fisheye cameras, thermal and depth cameras, EEGs). Lastly, wearable and mobile technologies that are needed to support experimentation and test novel learning (e.g., AR glasses, HMDs, location trackers, mobile phones, tablets) are provided. This infrastructure has been attained by and used in numerous national and international projects and has resulted in top-tier publications and numerous best paper awards (e.g., ACM IDC, LAK, *IEEE ICALT*, CSCL). Most of the lab's equipment is mobile in nature, and established collaborations with schools, museums and other organisations allow us to conduct studies in the wild (which in LT is considered to be the gold standard).

1.6 Research group's cooperation

Table 3. Current interactions with other disciplines, non-academic stakeholders and the potential importance of these for the research.

Interdisciplinary collaboration	The group's project portfolio includes several ongoing interdisciplinary collaborations at national and international levels. In the PaaSforChain project, we collaborate with SINTEF, DNV, Tsinghua University, Nanjing University and Southeast University (China) to study and develop platform technologies to facilitate supply chain management. Through the EUGAIN project, the group collaborates in European environments on gender research, and there is collaboration with researchers in psychology and linguistics in the MSCA ITN e-LADDA. LT is inherently interdisciplinary, with intense collaboration between CS and the learning sciences. Our group has ongoing collaborations with top educational institutes such as UCL's knowledge lab (the EU Exten(DT)^2 project, where Professor Giannakos holds an honorary professorship) and Kings College School of Education (the EU COMnPLAY project). Overall, via national and international projects, the group has collaborated with research groups from different disciplines and backgrounds, such as the Industrial Design department at TU Eindhoven, the School of Education at TU Munich, the Faculty of Behavioural and Social Sciences at the University of Twente, the school of education at UC Berkeley, and the Department of Educational Studies at the University of Athens. The group is also active in participating in interdisciplinary policy-making committees, such as the EC, UNESCO, the EU Parliament's education committee, and the Norwegian ministry of research and education.
Collaboration with other research sectors	GEMINI NSE is a collaboration with SINTEF and the University of Oslo to position the environments for larger research proposals with the aim of increasing the number of high-quality publications, the recruitment of researchers (in particular women) and the quality of teaching. The centre provides a broad environment and gives access to a wider range of funding opportunities. It also shows students at Masters level a range of career opportunities from applied research to basic research. The NFR IPIT project has shared best practices in SE education with Nanjing and Tsinghua Universities in China and the University of Michigan. Key adjunct positions are further evidence of collaboration with other sectors: prof. Cruzes is a lead security researcher at Visma, giving exposure to practical problems and ensuring relevance in research; at SimulaMet, prof. Dingsøyr collaborates on data collection and has access to a broader set of public environments in the centre for effective digitalisation of the public sector; and prof. Jaccheri served (until 2018) as a member of the Board of Directors in Reply SPA (with 6000 employees worldwide) worked to bridge the gap between academia and industry. Our group is an active member of the International Software Engineering Research Network, resulting in collaboration with Nanjing and Peking Universities (prof. Li) and Lund University (prof. Cruzes). This network has had a large impact on SE research and on how empirical SE is understood and conducted worldwide; it has also led to early discussions on novel research topics such as AI for SE. Publication #13 (prof. Cruzes) shows a method contribution resulting from this collaboration.
Transdisciplinary collaboration	We have strong connections with several stakeholder communities, including Save the Children, Design for Change and the YME Foundation. The work focuses primarily on the UN Sustainability Goals on gender, health and education. An example is the EduApp4Syria project with collaboration partners including the USAID, World Vision and All Children Reading. In the context of EU projects we have developed collaborations with international stakeholder communities such as Cybervoluntarios (Socratic Project), the European Physical Society (EPS), the Lisbon Council (SbS project) and the Science Museum of London (COMnPLAY project). At the national level, we have worked with several industry partners such as Equinor, Kantega and DNV, as well as public sector partners such as Lånekassen and the Norwegian Welfare Administration (NAV).

2. Research quality

2.1 Research group's scientific quality

In what follows, we evaluate the group's SE and LT research separately.

In the period from 2012 to 2022, the group published 33 scientific articles in top SE journals[1]. This is on the same level as the period from 2001 to 2011 (34 articles published) despite prof. Jaccheri being the only remaining faculty member from the previous period due to retirements and changes of fields. Group members have written a number of high-quality primary studies with high impact. For example, Publication 1 from the Agile 2.0 project (Project 3) is the most cited primary study on large-scale agile development (per year) and has had a wide impact beyond the empirical software engineering community, with over 35,000 downloads. The article by Professor Cruzes et al. (Publication 13) on case study synthesis is one of the most used method articles in the recent SE literature and has over 6,000 downloads. The group publishes in most top-tier SE journals and also in top journals in software security (prof. Li, Publication 11). The focus has been on relevance and quality over quantity of articles. Several PhD candidates have been able to publish in top journals as part of their doctoral work (Publications 6 and 12). We find scientific production at a high level: the volume of articles in top journals per full-time employee is slightly lower (86%) than for the similarly sized group at the IT University of Copenhagen. It is significantly lower than for the SE department at Blekinge Institute of Technology (54%), which is the highest-ranked SE research group in Europe (7th in the world for the period 2013–2020 in the *JSS* 2021 rankings). The international position of the group is shown through frequent programme committee memberships by group members (prof. Cruzes, prof. Dingsøyr, prof. Jaccheri) at ICSE, through organisation of the EASE conference in 2020 (general chairs: prof. Li and prof. Jaccheri), and upcoming organization of FSE'25 (general chairs: prof. Li and Associate prof. Montecchi) and through regular editorial work with special issues in top journals (*IST*, *JSS*, *IEEE Software*).

The group's LT research direction has been developed in recent years, and therefore we cannot compare with previous performance. Despite the small number of LT faculty members in the group (four) and the fact that the group has only recently been established (prof. Giannakos started in 2015, while assoc. prof. Papavlasopoulou and assoc. prof. Sharma started in 2021), all the LT members of the group have published regularly and at a high quantity in the most prestigious venues in the domain. In particular, during the last five years the group has had more than 30 publications among the most reputable LT journals[2], and an equally high number in the premier LT conference[2]. Several of our recent papers have received significant attention (e.g., the most cited *IEEE Transactions in Learning Technologies* paper of the last five years, a top-three cited paper in *Computers & Education*), as well as several paper awards by premier LT conferences (IDC '22, ITiCSE '20, CSCL '21, AIED '20, ECTEL '20, LAK '18, IEEE ICALT '17 and '18). In addition to their high scientific production, our group members are also active in senior editorial positions (e.g., Editor-in-Chief of *IJCCI*; Associate Editor of *IEEE TLT*, *BIT*, *IEEE TOE*; guest editorships in JCAL, *BJET*, *CHB*, *ACM TOCE*) and organisational roles (e.g., general and PC chairs for IDC, ITiCSE, AVI; frequent Associate Chairs for LAK, ECTEL, CHI). **In summary,** the group's LT members have compiled an outstanding record in LT research (at a high quantity in the most prestigious venues in the domain, with several recent being among the most cited and most downloaded), attracted a sizeable external funding (see table 4), have received best paper awards and distinctions from almost all the major venues of the field, have hosted some of the most important conference in the field (IDC'18, ITiCSE'20) and given frequent keynotes (e.g., GALA, IEEE iLRN, EGBL, LASI), and developed world-class research-based innovations (e.g., Kahoot!). Thus, we argue that the LT direction represents one of the most prestigious world-class research groups in the LT domain.

Group publications: https://www.ntnu.edu/idi/se#/view/publications

Individual members' publication lists: https://www.ntnu.edu/idi/se#/view/people

Table 4. List of projects.

Project 1: *COMnPLAY SCIENCE – Learning science the fun and creative way: coding, making, and play as vehicles for informal science learning in the 21st century)* **Period:** 2018–2021	**Project owner(s)**	Project funded under the European Commission Horizon 2020 framework Project Coordinator: NTNU PI: Giannakos
	Total budget and share allocated to research group	36,500,000 NOK, of which 6,500,000 NOK is allocated to the research group
	Objectives and outcomes and link to website	The project identified promising play-based practices taking place outside formal science classrooms, and developed appropriate technology to support prolonged engagement. We conducted large-scale (ten countries) and in-depth learner-centred participatory empirical research on selected practices. In addition to the numerous research publications resulting from the large-scale studies run collaboratively with other European organisations (e.g., the Science Museum of London, Kings College), the project's outcomes include • a Web-based game promoting and supporting the continuous prolonged engagement of learners and their facilitators in the field research; • an online inventory of all the identified and pooled practices, appropriately categorised and annotated in light of the findings of the research, available to stakeholders and the public; • the COMnPLAY SCIENCE Knowledge Kit, a modular set of reader-friendly resources and publications encapsulating the findings of the project. **Project website:** https://comnplayscience.eu/
Project 2: *Future Learning – Orchestrating 21st Century Learning Ecosystems using Analytics* **Period:** 2016–2020	**Project owner(s)**	Project funded through the "Young Research Talents" call from the Research Council of Norway (NFR) Project Coordinator: NTNU PI: Giannakos
	Total budget and share allocated to research group	7,000,000 NOK, all of which is allocated to the research group
	Objectives and outcomes and link to website	The aim of the project is to investigate how the insights of learning analytics can inform us to better orchestrate different e-learning tools and learning practices, in particular: • What kinds of learning analytics can help orchestrate a learning ecosystem? • How can different learning analytics be integrated to improve educators' decisions? • How do integrated learning analytics contribute to the creation of a more meaningful and efficient set of technologies for learning?

		The project resulted in a couple of dozen publications in top-tier venues (including LAK, IEEE TLT, JCAL), distinctions (best demo at LAK 2018) and learning systems used by thousands of students. Moreover, the LA4LD framework that resulted from the project is now used by several organisations, including the Norwegian ministry of education and research in defining their policy for learning analytics. **Project website:** https://app.cristin.no/projects/show.jsf?id=529009
Project 3: *Agile 2.0* **Period:** 2014-2020	**Project owner(s)**	Project funded through the IKTPLUSS call from the Research Council of Norway (NFR) Project Coordinator: SINTEF PI: Dingsøyr
	Total budget and share allocated to research group	25,000,000 NOK, of which 5,000,000 NOK is allocated to the research group
	Objectives and outcomes and link to website	This project developed a knowledge-based model of software development that understands and improves distributed agile development, large-scale agile development and use of agile methods in developing safety-critical software. Secondary objectives: 1) *Establish an empirical foundation* by synthesising prior knowledge and extending this knowledge through case studies, action research and surveys; 2) *Develop new theory* to explain the fundamental mechanisms of agile software development in three critical areas; 3) *Improve efficiency and effectiveness* of software development in the participating companies. Delivered 24 journal articles, 20 conference papers, 13 popular science articles, one PhD thesis, 12 Masters theses. **Project website:** https://app.cristin.no/projects/show.jsf?id=450634
Project 4: *SOS-Agile* **Period***:* 2015–2021	**Project owner(s)**	Project funded through the IKT Pluss call from the Research Council of Norway (NFR) Project Coordinator: SINTEF PI: Cruzes
	Total budget and share allocated to research group	25,000,000 NOK, of which 4,000,000 NOK is allocated to the research group
	Objectives and outcomes and link to website	The principal objective of the project was to develop a research-based model of security engineering for agile software development through science of security. Sub-goals: 1) Establish an empirical foundation for agile development of secure software by application and validation of security engineering approaches in industrial case studies; 2) Develop new theory to explain the fundamental

		mechanisms of science of security in agile development; 3) Develop and apply innovative approaches and tools for improving security in agile development; 4) Increase the maturity of software security practices in Norwegian public and private software organisations; 5) Enhance the quality and capacity of Norwegian research through university courses and education of a skilled workforce of PhDs, postdocs and Masters students in the area. **Outcomes:** The project delivered 99 scientific results, one PhD and two postdocs, one of whom is now Associate Professor at HVL. **Project website:** https://app.cristin.no/projects/show.jsf?id=501529
Project 5: *PaaSforChain – Platform as Service Technologies for High-performance Blockchain-based Supply Chain Management Systems* **Period:** 2021–2023	**Project owner(s)**	Project funded through the IKTPLUSS call from the Research Council of Norway (NFR) Project Coordinator: NTNU (the project had two coordinators, one in Norway and one in China) PI: Li
	Total budget and share allocated to research group	27,109,000 NOK, of which 7,635,000 NOK is allocated to the research group
	Objectives and outcomes and link to website	**Objectives:** The PaaSforChain project is a Chinese-Norwegian Collaborative Project on Digitalisation financed by the NFR and the Ministry of Science and Technology of China. It studies and develops platform technologies to facilitate supply chain management, which will be certified to guarantee immutability while collating the asset data with metadata during transportation using blockchain technology as the core enabler of the system. The project covers the fishermen in the high north over no satellite-based networks or high-speed infrastructure of 4G/5G-LTE, and cloud systems with heterogeneous, distributed and enormous data. **Outcomes:** This project funded a PhD (J. Notland) and a postdoc (P. Damilare Oyinloye). The project has delivered 53 scientific articles, 26 patents, three industrial seminars, three exhibitions, and one prototype. **Project website:** https://www.ntnu.edu/paasforchain
Project 6:	**Project owner(s)**	Project funded through Nordic research cooperation (NordForsk) Project Coordinator: Technical University of Denmark (DTU) PI: Li

CIRCit – Circular Economy Integration in the Nordic Industry for enhanced sustainability and competitiveness **Period:** 2017–2021	**Total budget and share allocated to research group**	20,795,000 NOK, of which 4,477,000 NOK is allocated to the research group
	Objectives and outcomes and link to website	**Objectives**: The CIRCit research project is part of the Nordic Green Growth Research and Innovation Programme funded by NordForsk. It spans the five Nordic countries: Denmark, Norway, Finland, Iceland and Sweden. Using a number of action research methods, CIRCit's objective is to support the Nordic industry to discover and implement the opportunities of circular economy, through the development, testing and implementation of science-based tools. NTNU focuses on developing principles, tools and methodologies for a smart circular economy. **Outcome:** The project funded a PhD student (E. Kristoffersen) and a postdoc (Z. Li). The project delivered 36 scientific articles, 22 popular articles and 32 tools. **Project website:** https://circitnord.com/
Project 7: *Exten(DT)² – Extending Design Thinking with Emerging Digital Technologies* **Period:** 2022–2025	**Project owner(s)** (project leaders organisation)	Project funded under the European Commission Horizon Europe framework Project Coordinator: Linnaeus University PI: Papavlasopoulou
	Total budget and share allocated to research group	30,600,000 NOK, of which 6,000,000 NOK is allocated to the research group
	Objectives and outcomes (planned or actual) **and link to website**	Exten(DT)² uses emerging technologies (such as such as artificial intelligence, augmented reality, and 3D printing) to enhance pedagogical value, sustainable digitisation and potential for wide deployment of design thinking (DT). The aim is to leverage the implementation, monitoring and evaluation of DT projects and enhance our understanding of how they can support twenty-first-century skills development. **Outcomes:** The project funds a PhD student (I. Possaghi) and a postdoc (F. Zhang) and has already resulted in the implementation of DT activities in schools in Norway, the extension of digital tools with learning analytics capabilities, and the development of the first version of a framework. **Project website:** https://extendt2.eu/
Project 8: *e-LADDA –*	**Project owner(s)** (project leaders organisation)	Project funded under the European Commission Horizon Europe framework Marie Skłodowska-Curie Actions (MSCA) Doctoral Networks Project Coordinator: NTNU; PI: Jaccheri

Early Language Development in the Digital Age Period: 2019–2024	**Total budget and share allocated to research group**	45,000,000 NOK, of which 4,000,000 NOK is allocated to the research group
	Objectives and outcomes (planned or actual) **and link to website**	The objective of e-LADDA is to establish whether the new and intuitive interactions afforded by digital tools impact young children's language development in a positive or an adverse way. It also aims to identify exactly what factors in both the technology itself and the communication channel advance or impede language learning and growth. This goal is pursued in e-LADDA from a highly interdisciplinary and cross-sectorial perspective, bridging research disciplines and methodologies, and in collaboration with industry and the non-academic public sector. **Outcomes:** The project funds a PhD student (I. El Shemy) and has already resulted in a prototype and a couple of high-quality papers concerning the design and development of AR mobile technology to support autistic children's language learning. **Project website:** https://www.ntnu.edu/e-ladda
Project 9: *Surrounded by Science: Learning paths towards science proficiency* **Period:** 2021–2024	**Project owner(s)** (project leaders organisation)	Project funded under the European Commission Horizon Europe framework Project Coordinator: University of Twente PI: Giannakos and Papavlasopoulou
	Total budget and share allocated to research group	25,000,000 NOK, of which 2,750,000 NOK is allocated to the research group
	Objectives and outcomes (planned or actual) **and link to website**	The Surrounded by Science project develops a systematic assessment methodology to analyse the impact of out-of-school science activities. The project designs a digital toolbox of innovative research instruments to collect data from citizens participating in science-related activities. The digital toolbox consists of two main apps: the Science Chaser and the Science Booster. The Science Chaser app monitors users' science-related activities and provides guidance and recommendations for related future activity. The Science Booster is a self-reflection and advice tool for informal science education organisations aiming to support a more effective design of out-of-school science learning activities. The Surrounded by Science consortium utilises those tools to conduct field studies and implement data collections that allow us to assess the impact of specific out-of-school activities. This project funds a postdoc (E. Chatzidaki) and has resulted in the design and development of the digital toolbox. Moreover, the toolbox has been used in ten different European countries and has monitored engagement in science-related experiences in some thousands of individuals. **Project website:** https://surroundedby.science/

Project 10: *INITIATE – INnovation through bIg daTa and socIal enTreprEneurship* **Period:** 2018–2021	**Project owner(s)** (project leaders organisation)	Project funded under the European Commission Horizon 2020 framework Marie Skłodowska-Curie Actions (MSCA) Individual Fellowships Project Coordinator: NTNU; PI: Jaccheri
	Total budget and share allocated to research group	2,319,685 NOK, all of which is allocated to the research group
	Objectives and outcomes (planned or actual) **and link to website**	INITIATE examined how to successfully exploit big data towards achieving social good and sustainable change. Extracting insights from the different stakeholders involved in the social innovation process (entrepreneurs, policy makers, social innovators), the project developed and tested a framework of best practices. INITIATE offered practical and theoretical implications through the development of prototype applications that showcased the impact of big data on addressing societal challenges **Outcome:** INITIATE is a prestigious MSCA individual fellowship that funded a postdoc fellow (Dr Ilias Pappas) from 2018 to 2021. The project examined how big data analytics affordances facilitate the social innovation process that may lead to societal change in a developing country context. INITIATE resulted in numerous scientific articles in top venues and collaborations with USA and Australia. **Project website:** https://app.cristin.no/projects/show.jsf?id=573526

Table 5. Research group's contributions to publications.

Publication 1 "Exploring software development at the very large-scale: A revelatory case study and research agenda for agile method adaptation." *Empirical Software Engineering*, *23*, 490–520. 2018. https://link.springer.com/article/10.1007/s10664-022-10230-6 *This paper is based on the NFR project Agile 2.0.*	**Authors**	**T. Dingsøyr**, N. B. Moe, T. E. Fægri and E. A. Seim
	Short description	Revelatory exploratory case study of a large-scale agile development programme with 175 participants at peak in 12 development teams. Focus on programme organisation, customer involvement, architectural work and inter-team coordination. The article proposes new research directions on adaptation of agile methods in large programmes. More than 35,000 downloads.
	Research group's contribution	Professor Dingsøyr organised access to the case and led the organisation of data collection and analysis and reporting. He wrote first drafts of the introduction, and most of the background, method, discussion and conclusion, and results on the topic of inter-team coordination.

Publication 2 "A longitudinal explanatory case study of coordination in a very large development programme: The impact of transitioning from a first- to a second-generation large-scale agile development method." *Empirical Software Engineering*, *28*(1), 49. 2023. https://link.springer.com/article/10.1007/s10664-022-10230-6 *This paper is based on the NFR project Agile 2.0.*	**Authors**	**T. Dingsøyr**, **F. O. Bjørnson**, J. Schrof and T. Sporsem
	Short description	Explanatory case study of coordination in a large-scale agile development programme with 200 participants at peak in ten development teams. Focus on how inter-team coordination changed as the programme transitioned from what we define as a first-generation to a second-generation large-scale agile development method. Contribution to theory on coordination in this context, rich description of the case, and contribution in defining generations of methods. One of very few longitudinal studies of large-scale agile development. More than 8,000 downloads.
	Research group's contribution	Prof. Dingsøyr and Dr Bjørnson: data collection. All authors: analysis, with Dr Bjørnson doing the initial work and Professor Dingsøyr leading the final analysis round. Prof. Dingsøyr obtained access to the case and handled reporting to the case participants. The third and fourth authors conducted the literature reviews and wrote the initial background section, which Professor Dingsøyr author expanded and revised.
Publication 3 "Learning analytics for learning design: A systematic literature review of analytics-driven design to enhance learning." *IEEE Transactions on Learning Technologies*, *12*(4), 516–534. 2019. https://ieeexplore.ieee.org/document/8454297 *This paper is based on the NFR project Future Learning.*	**Authors**	**K. Mangaroska** and **M. Giannakos**
	Short description	This work conducts a systematic and thorough analysis of what and how learning analytics have been used to inform learning design decisions. The results depict the ongoing design patterns that emerged from the synergy of learning analytics and learning design. The paper devises the learning analytics for a learning design model (LA4LD) that is currently used by different institutions (including the Norwegian ministry of research and education). This work was published in the leading technical journal of LT and, based on Scopus, is the journal's most cited paper.
	Research group's contribution	This paper is based on the NFR project FUTURE LEARNING. Mangaroska (former PhD student funded by the NFR) together with Professor Giannakos conducted the literature search and analysis, as well as the writing of the paper.
	Authors	**M. N. Giannakos**, **K. Sharma**, **I. O. Pappas**, V. Kostakos and E. Velloso
	Short description	The design of learning technologies uses computer logs as the primary data source for modelling and predicting learning behaviour. This paper sets out to quantify what advantages physiological sensing techniques provide for the design of learning technologies. We conducted a lab study with 251 sessions focusing on skills development. We collected click-stream, eye-tracking, EEG, video, and wristband

Publication 4 "Multimodal data as a means to understand the learning experience." *International Journal of Information Management*, *48*, 108–119. 2019. https://doi.org/10.1016/j.ijinfomgt.2019.02.003 *This paper is based on the NFR project XDesign.*		data. Our analysis shows that traditional click-stream models achieved an 18% error rate when we performed feature selection, while for fused multimodal the error dropped up to 6%. This paper shapes the future of learning technology research by pointing out the substantial benefits of physiological sensing.
	Research group's contribution	This research was implemented to support Giannakos' ERC reapplication (which went through to the interview stage on the first attempt). Giannakos initiated the paper during his visit to the Univ. of Melbourne; Giannakos and Sharma: data collection; Sharma: data analysis. Giannakos wrote the first draft of the paper; the third, fourth and fifth authors participated in the initial ideation of the paper, advised on the data collection and analysis, and contributed to the writing and revision of the paper.
Publication 5 "Runtime evolution of Bitcoin's consensus rules." *IEEE Transactions on Software Engineering*, *49*(9), 4477–4495. 2023. *https://ieeexplore.ieee.org/document/10224537* *This paper is based on the NFR project PaaSforChain.*	**Authors**	**J. S. Notland**, **M. Nowostawski** and **J. Li**
	Short description	This study investigates the Bitcoin consensus evolution by analysing over a decade of data from Bitcoin's development channels using Strauss's grounded theory approach and root cause analysis. The results show nine deployment features which form nine deployment techniques and ten lessons learned. Our results illustrate how different deployment techniques fit different contexts and pose different levels of consensus failure risks. Furthermore, we provide guidelines for risk minimisation during consensus rule deployment for blockchain in general and Bitcoin in particular.
	Research group's contribution	This paper is based on the NFR project PaaSforChain. Notland (a PhD student funded by the NFR) together with Li (main supervisor) conducted the study design, data analysis, and writing of the paper.
Publication 6 "Testing and verification of neural-network-based safety-critical control software: A systematic literature review." *Information and Software Technology*, *123*, 106296. 2020. https://doi.org/10.1016/j.infsof.2020.106296	**Authors**	**J. Zhang** and **J. Li**
	Short description	This study provides an overview on the testing and verification (T&V) of NN-based control software in safety-critical domains. The T&V approaches were categorised into five high-order themes. From the industry perspective, improving the interpretability of NNs is a crucial need in safety-critical applications. We also investigated nine safety integrity properties within four major safety lifecycle phases to investigate the achievement level of T&V goals in IEC 61508-3. The results show that little effort has been invested in achieving repeatability, and no previous work focused on defined testing configuration or defence against common cause failure.

This paper is based on a joint project between NTNU and DTU, financed by the institutions.	**Research group's contribution**	This paper is based on a joint project between NTNU and DTU, internally financed by NTNU. Zhang (the PhD student funded by the project) together with Li (main supervisor) conducted all tasks for writing the paper.
Publication 7 "Assessing cognitive performance using physiological and facial features: Generalizing across contexts." *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *4*(3), 1–41. 2020. https://doi.org/10.1145/3411811 *This paper is based on Future Learning and XDesign NFR projects (which funded Sharma) and SNSF project (which funded Niforatos).*	**Authors**	**K. Sharma**, **E. Niforatos**, **M. Giannakos** and V. Kostakos
	Short description	Sensing and ML advances have enabled the unobtrusive measurement of physiological responses and facial expressions to estimate cognitive performance. However, it remains unclear whether physiological responses and facial expressions used in one particular task (e.g., gaming) can reliably assess cognitive performance in another task (e.g., coding), because complex and diverse tasks often require varying levels and combinations of cognitive processes. In this paper, we measure the cross-task reliability of physiological and facial responses. Specifically, we assess cognitive performance based on physiological responses and facial expressions for 123 participants in four independent studies. Our results show that the extracted features generalise and can reliably predict cognitive performance across a diverse set of tasks.
	Research group's contribution	The four independent studies were conducted by the NTNU researchers: Sharma conducted the data analysis; the first and second authors wrote the first draft of the paper; the third and fourth authors participated in the initial ideation of the paper, advised on the data collection/analysis, and contributed to the writing of the paper.
Publication 8 "The effect of using Kahoot! for learning: A literature review." *Computers & Education*, *149*, 103818. 2020. https://doi.org/10.1016/j.compedu.2020.103818 *This paper is based on the Kahoot! research.*	**Authors**	**A. I. Wang** and **R. Tahir**
	Short description	This paper is based on Kahoot!, a game-based learning platform developed in our group by prof. Wang and his MSc students. It is among the most popular game-based learning platforms, with 100 million monthly active unique users, and is used by 50% of US K-12 students. This article presents the results of a literature review on the effect of using Kahoot! for learning and, more specifically, on how Kahoot! affects learning performance, classroom dynamics, and students' and teachers' attitudes. This represents how years of research in our group contributed to the development of one of the most successful and impactful learning technologies of all time.
	Research group's contribution	Wang conducted the initial literature search, analysis and writing, while Tahir complemented the search, analysis and writing; both authors contributed to the final writing and revision of the paper.

Publication 9 "Fitbit for learning: Towards capturing the learning experience using wearable sensing." *International Journal of Human-Computer Studies*, *136*, 102384. 2020. https://doi.org/10.1016/j.ijhcs.2019.102384 *This paper is based on the Future Learning and XDesign NFR projects.*	**Authors**	**M. N. Giannakos**, **K. Sharma**, **S. Papavlasopoulou**, **I. O. Pappas** and V. Kostakos
	Short description	The assessment of learning during class activities mostly relies on standardised questionnaires to evaluate the efficacy of the learning design elements. However, standardised questionnaires place additional strain on students, do not provide "temporal" information during the learning experience, require considerable effort and language competence, and sometimes are not appropriate. To overcome these challenges, we propose using wearable devices, which allow for continuous and unobtrusive monitoring of physiological parameters during learning. We quantify how well we can infer students' learning experience from wrist-worn devices capturing physiological data. Our analysis shows that wrist data can predict the learning experience with 11% error and that 6.25 min (SD = 3.1 min) of data are needed to achieve a reliable estimate (i.e., 13.8% error). This demonstrates how quantified-self technologies can be used for self-monitoring, evaluation and reflection in learning.
	Research group's contribution	Giannakos initiated the paper during a visit to the University of Melbourne; Papavlasopoulou: data collection; Sharma: data analysis. Giannakos wrote the first draft of the paper; the fourth and fifth authors participated in the initial ideation of the paper, advised on the data collection and analysis, and contributed to the writing.
Publication 10 "Exploring students' cognitive and affective states during problem solving through multimodal data: Lessons learned from a programming activity." *Journal of Computer Assisted Learning*, *38*(1), 40–59. 2021. https://doi.org/10.1111/jcal.12590 *This paper is based on the NFR project FUTURE LEARNING.*	**Authors**	**K. Mangaroska**, **K. Sharma**, D. Gašević and **M. Giannakos**
	Short description	In this study, we examined how the theory-informed measures from multimodal data that we selected as proxies for cognitive and affective dimensions of learning are associated with student performance, and in comparison to prior knowledge. High-frequency temporal data was collected with a camera, an EEG, and an eye-tracker in the context of a code-debugging activity. Our findings demonstrate that attention, convergent thinking, and frustration were positively correlated with students' successful code-debugging (i.e., performance) and frequently manifested by high-performing participants. Cognitive load, memory load and boredom were negatively correlated with students' performance.
	Research group's contribution	Mangaroska (a former PhD student funded by the NFR) initiated the paper; Mangaroska and Sharma collected the data; Mangaroska wrote the first draft of the paper; the third and fourth authors participated in the initial ideation of the paper, advised on the data collection and analysis, and contributed to the writing.

Publication 11 "AST-SafeSec: Adaptive stress testing for safety and security co-analysis of cyber-physical systems." *IEEE Transactions on Information Forensics and Security*, *18*, 5567–5579. 2023. https://ieeexplore.ieee.org/document/10231138 *This paper is based on a project internally financed by NTNU.*	**Authors**	**N. Kaloudi** and **J. Li**
	Short description	In this paper, we propose AST-SafeSec, an analysis methodology for both safety and security aspects that utilises reinforcement learning to identify the most likely adversarial paths at various normal or failure states of a cyber-physical system that can influence system behaviour through its sensor data. The methodology is evaluated using an AV scenario by incorporating a security attack into the stochastic sensor elements of a vehicle. Evaluation results show that the methodology analyses the interaction of malicious attacks with random faults and identifies the incident caused by the interactions and the most likely path that leads to the incident.
	Research group's contribution	Kaloudi (the PhD student funded by the project) together with Li (main supervisor) conducted all tasks for writing the paper.
Publication 12 "Exploring the intersection between software industry and software engineering education: A systematic mapping of software engineering trends." *Journal of Systems and Software*, *172*, 110736. 2021. https://doi.org/10.1016/j.jss.2020.110736 *This paper is based on the NFR project IPIT.*	**Authors**	**O. Cico**, **L. Jaccheri**, **A. Nguyen-Duc** and H. Zhang
	Short description	The paper investigates the extent to which SE education addresses major SE trends in the academic setting. This paper classifies 126 works based on their investigated SE trends, specifically SE processes and practices, teaching approaches, and the evolution of SE trends over time. The study points out the possible gaps between software industry and education, which implies actionable insights for researchers, educators and practitioners.
	Research group's contribution	The PhD student supervised by Jaccheri and Nguyen-Duc conducted the review. All the authors were involved in the drafting of the paper and quality assurance.
Publication 13 "Case studies synthesis: A thematic, cross-case, and narrative synthesis worked example." *Empirical Software Engineering*, *20*, 1634–1665. 2015. https://doi.org/10.1007/s10664-014-9326-8	**Authors**	**D. S. Cruzes**, T. Dybå, P. Runeson and M. Höst
	Short description	Case studies are often used for investigating SE practices. They are characterised by their flexible nature and multiple forms of data collection, and are mostly informed by qualitative data. Synthesis of case studies is necessary to build a body of knowledge from individual cases. The objective of this research is to demonstrate the similarities and differences of the results and conclusions when applying three methods of synthesis, and to discuss the challenges of synthesising case study evidence in SE.

This paper is based on the NFR project SOS-Agile.	**Research group's contribution**	Cruzes is the main author and main driver of the research.
Publication 14 "Continuous software security through security prioritisation meetings." *Journal of Systems and Software*, *194*, 111477. 2022. https://doi.org/10.1016/j.jss.2022.111477 *This paper is based on the NFR project SOS-Agile.*	**Authors**	I. A. Tøndel and **D. S. Cruzes**
	Short description	Software security needs to be a continuous endeavour in current software development practices. Frequent software updates, paired with an ongoing flow of security breaches, require software companies to address software security throughout development and post deployment. Prescriptive software security approaches do not match well with agile software development and its emphasis on self-management. Agile approaches are, however, in favour of meetings as a coordination and problem solving strategy. This article investigates the role of regular security meetings centred on making security priorities and decisions for achieving continuous software security.
	Research group's contribution	This paper is part of Tøndel's PhD and was produced in the context of the SoS-Agile project that was managed by Cruzes. This research was a close collaboration between the two authors.
Publication 15 "Building pipelines for educational data using AI and multimodal analytics: A 'grey-box' approach." *British Journal of Educational Technology*, *50*(6), 3004–3031. 2019. https://doi.org/10.1111/bjet.12854 *This paper is based on the Future Learning and XDesign NFR projects.*	**Authors**	**K. Sharma**, **Z. Papamitsiou** and **M. Giannakos**
	Short description	LT researchers have been using ML methods in a "black-box" approach. This work proposes a methodological shift from the black-box approach to a "grey-box" approach that bridges the theory-/literature-driven (feature extraction) "white-box" approach with the computation-/data-driven (feature fusion) black-box approach. This allows us to utilise data features that are educationally and contextually meaningful. This paper aims to extend current methodological paradigms, and puts into practice the proposed approach in a case study taking advantage of new, cutting-edge interdisciplinary work on building pipelines for educational data.
	Research group's contribution	Sharma is the main author and contributor; the second and third authors contributed to the initial ideation of the paper, advised on the data collection, and contributed to the writing and revision of the paper.

Table 6. List of monographs/scientific books.

1	**Giannakos, M.** (2022). Experimental studies in learning technology and child–computer interaction. Springer. https://link.springer.com/book/10.1007/978-3-031-14350-2
2	Mougiakou, S., Vinatsella, D., Sampson, D., **Papamitsiou, Z.**, **Giannakos, M.**, & Ifenthaler, D. (2023). Educational data analytics for teachers and school leaders. Springer. https://link.springer.com/book/10.1007/978-3-031-15266-5
3	Sampson, D., **Papamitsiou, Z.**, Ifenthaler, D., **Giannakos, M.,** Mougiakou, S., & Vinatsella, D. (2022). Educational data literacy. Springer. https://link.springer.com/book/10.1007/978-3-031-11705-3
4	Myklebust, T., & **Stålhane, T.** (2018). The agile safety case. Springer. https://link.springer.com/book/10.1007/978-3-319-70265-0
5	Hanssen, G. K., **Stålhane, T.**, & Myklebust, T. (2018). SafeScrum®-Agile development of safety-critical software. Springer. https://link.springer.com/book/10.1007/978-3-319-99334-8
6	**Giannakos, M.**, Spikol, D., Di Mitri, D., **Sharma, K.**, Ochoa, X., & Hammad, R. (Eds.). (2022). The multimodal learning analytics handbook. Springer. https://link.springer.com/book/10.1007/978-3-031-08076-0
7	Chorianopoulos, K., Divitini, M., Hauge, J. B., **Jaccheri, L.**, & Malaka, R. (Eds.). (2015). Entertainment computing. Springer. https://link.springer.com/book/10.1007/978-3-319-24589-8
8	**Pappas, I. O.**, Mikalef, P., Dwivedi, Y., **Jaccheri, L.**, Krogstie, J., & Mäntymäki, M. (Eds.) (2019). Digital transformation for a sustainable society in the 21st century. Springer. https://link.springer.com/book/10.1007/978-3-030-39634-3
9	**Li, J.**, **Jaccheri, L.**, **Dingsøyr, T.**, **&** Chitchyan. R. (Eds.) (2020). Evaluation and Assessment in Software Engineering (EASE 2020). Association for Computing Machinery, New York, NY, USA. https://dl.acm.org/doi/proceedings/10.1145/3383219
10	**Giannakos, M.**, Sindre, G., Luxton-Reilly, A., & Divitini, M. (Eds.) (2020). Innovation and Technology in Computer Science Education (ITiCSE 2020). Association for Computing Machinery, New York, NY, USA. https://dl.acm.org/doi/proceedings/10.1145/3341525

2.2 Research group's societal contribution

The group contributes to societal development in several different ways. First, the group has developed some of the most revolutionary technologies in the world that have changed the way millions of people teach and learn. Besides Kahoot!, which has hosted over 9 billion participants in hundreds of millions of learning sessions, with half of US teachers and students using it, the group has also been involved in the development of technologies such as BitPet (which became one of the 20 Niantic managed partners), EduApp4Syria (which helps Syrian children learn how to read in Arabic and improves their psychosocial wellbeing), ProTuS (an adaptive and interactive learning tool that received the LAK '18 best demo award and has been used by thousands of students in Norway and abroad), and PaaSforChain (a blockchain-based application that supports the traceability of seafood exportation from Norway to China). Second, the group actively participates in policy and resource development in the areas of SE and LT. In particular, group members have initiated the GEMINI National Center in SE and developed several SE resources that have been used by thousands. We have also funded the national network for game developers (JoinGame) that has contributed to the coordination and strengthening of the Norwegian game industry. Moreover, the group has contributed to the development of the Learn2Analyze MOOC, which has strengthened the educational data analytics competencies of thousands of students and teachers, and contributed to the report of the Norwegian Ministry of Education and Research on implementing learning analytics in Norway (NOU 2023: 19). Third, the group has contributed to diversity, equity and inclusion (EDI) in CS, both nationally and internationally. In particular, the group has developed an outreach programme and syllabus for introducing high school students to programming (Kodeløypa), allowing hundreds of high school students every year, especially female students, to experience CS and seriously consider it as a career choice. Our group has also led and participated in several national and international programmes on EDI and gender balance in IT (EU EUGAIN network, NFR IDUN project, Women STEM UP).

Table 7. The research group's societal contribution, including user-oriented publications and products (patents, software or process innovations)

No.	Name of publication/product	Date	Link to the document
1	Kahoot!	2013 (first Kahoot! company)	Kahoot! is a game-based learning platform where people can create, share, and play quiz-style games that transform the classroom into a game show, it utilizes elements of gamification, microlearning and social learning. You can find more details about the platform as impact case
2	PaaSforChain software prototype	2022	PaaSforChain is a blockchain-based application that supports the traceability of seafood exportation from Norway to China. It was developed in the context of PaaSforChain project.
3	PlayPulse (software and hardware innovations)	2015 (PlayPulse prototype)	PlayPulse is an exergame platform that turns high-intensity interval spinning into a fully-fledged video gaming experience by turning an exercise bike into a game controller. It is based on interdisciplinary research in games, and the health benefits of high-intensity training.
4	BitPet	2020	BitPet is an AR multiplayer mobile game where players take care of virtual pets, it is based on research in co-located social engagement using game technology, and how video games can motivate physical activity. BitPet has become one of the 20 Niantic managed partners.
5	ProTuS interactive learning analytics tool	2016	ProTuS is an interactive learning analytics tool that aggregates and harmonises learner analytics coming from different systems and quantifies learners' performance through a set of indicators. ProTuS has wone the Best Demo Award at LAK'18 (premier LT conference), and is used by thousands of students in Norway and abroad (ERCIM news, video demonstration).
6	Learn2Analyze MOOC (on educational data analytics)	2021	The Learn2Analyze MOOC supports the development of core and advanced competences for educational data analytics of online and blended teaching and learning. It was funded by EU and has been created in collaboration with other leading universities and the EdTech industry.
7	Kodeløypa (outreach CS programme for high-school students)	Started in 2015 and still active	Kodeløypa is an outreach programme and syllabus for introducing high school students to programming. Every year Kodeløypa attracts several hundreds of students, see info video.
8	JoinGame (national network for game developers)	2007-2015 (NFR funding ceased in 2015)	JoinGame is a national network focusing on strengthening the Norwegian computer game industry through skills development and by intensifying collaboration with Norwegian and international game research. NFR funding ceased in 2015 but the network continued.
9	Contribution to NOU government report (NOU 2023: 19) on learning analytics in Norwegian education.	2020-2023	NOUs are government reports whose purpose is to present and discuss the knowledge base and possible courses of action. Our group has contributed in the national Expert Commission on Learning Analytics and the development of the respective LA report and NOU 2023: 19.
10	Webinar in Large-Scale Agile Development offered via the project management institute platform	2020	One of the most popular webinars in project management institute platform is developed by our group, the webinar on Coordinating Knowledge Work in Multiteam Programs: Findings From a Large-Scale Agile Development Program.

3. Challenges and opportunities

The group does not have a formal role at the section or department levels. The group's strategy comes from NSE's mission on SE (developed together with SINTEF and the University of Oslo) and LCI's mission on LT (developed in the context of the lab). Therefore, a dedicated group with formal leadership and a proper strategy could better exploit opportunities between planned and running portfolios of projects, and establish a common infrastructure for research. This will make the environments more visible internationally, and ensure their presence in decision making and operations at department level.

Given that the group has a very large portfolio of competitive projects and the network and competence necessary to strengthen it, an opportunity exists to streamline operations and increase research activity. In particular, the group is one of only a few nationally with experience in coordinating large EU projects, having reached the final stage of ERC and developed world-class research-based innovations (e.g., Kahoot!). This experience provides a solid foundation for scaling up our project portfolio and developing successful applications for long-term funding (e.g., from the ERC and SFF).

The new model for university funding focuses mainly on teaching indicators. Although the model will not have a direct impact on the department's economy, the removal of research indicators might disorient the group's intensive focus on research and demotivate faculty members. This is particularly important for our group, where faculty members attract sizeable competitive funding, publish in top venues and undertake community leadership roles such as editorial responsibilities for leading journals and organisation of conferences. To further empower our faculty members, we can develop internal schemes that recognise their work, incentivise them with research resources and possibly offload some of their teaching responsibilities.

Although we have a strong presence in the most prestigious international venues[1,2] (including general chairs in EASE, IDC, ITiCSE, FSE and IFIP ICEC, and PC members in ICSE, LAK and CHI), we should strive to strengthen our position with leadership roles in the most prestigious venues such as the ICSE and LAK community and in top journals such as *TSE*, *ESEM* and *TOSEM*. To succeed, we need a larger base of PhD and postdoc candidates, which can be established through larger research projects or a broader portfolio. The group has very good ties to the software industry through national research collaborations and direct contact with industry bodies who act as customers on courses. The group has a long history in SE education and attracts skilled Masters students. We also have several researchers with track records that enable us to seek research funding in competitive programmes.

In SE, there are few PhD candidates relative to the number of senior researchers, which limits the group's potential. A major challenge is the attractiveness of SE positions in the industry, and the fact that our own students are typically recruited a year prior to graduation. Some of the empirical work with the Norwegian software industry requires people with mastery of a Scandinavian language. International recruitment is particularly challenging due to national processing times for countries outside the EU, and this is currently a limiting factor on the group's research capacity. We plan to develop a recruitment strategy that uses our collaboration with SINTEF, industrial PhD candidates, integrated PhDs and earlier involvement to exploit the broad recruitment base from large undergraduate- and graduate-level courses. Furthermore, we have several women in the group who act as role models for recruitment to address the general challenge of underrepresentation of women.

The group mainly consists of newly employed faculty members with a strong focus on empirical SE and LT. Although we intend to maintain this focus along with our leading position in these areas, the scope can be sustainably extended to promising areas such as quality and security, SE for AI, sustainable SE, and AI and context-aware LT. We are currently in the process of opening a new position in software quality and security that will help us expand our group and focus and play a central role in large national and international projects on cybersecurity.