*The domain specific frame of reference describes the profile of CreaTe and compares it with more or less similar programmes in the Netherlands and abroad.*

# A

# Domain Specific Frame of Reference

## A.1 What is Creative Technology

When we started the programme Creative Technology in 2009 we identified the demand for creative academic engineers, with good knowledge and skills in Computer Science (CS), Electrical Engineering (EE), Design, Entrepreneurship and Arts. These engineers should be able to design relevant human-centred hardware devices, web applications and (serious) games and be able to start their own companies. By nature *Creative Technology is an interdisciplinary field* (Figure A.1). This implies that there is less in-depth knowledge of the various disciplines but, on the other hand, there is broader knowledge of several domains, enabling the integration of the various disciplines.

Creative Technology is an interdisciplinary field

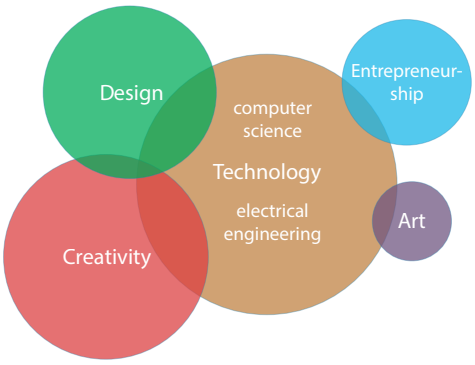



**Figure A.1** Interdisciplinary character of Creative Technology

The Creative Technologist must have good basic intellectual skills, enabling a solid scientific approach and must be very competent in designing, in co-operating and communication and in taking into account the temporal and social context. The Creative Technologist has a focus on *design-oriented research* and is less expected to do fundamental research in the 'disciplinary pillars', mentioned in Section A.2. This profile qualitatively indicates a strong orientation on design, teamwork and entrepreneurship.

Design-oriented research

No authoritative description of a Creative Technologist could be found. Therefore, this domain-specific frame of reference, is based on what is found in demands for electrical engineers, computer scientists, the input from our advisory board and a benchmark study of more or less similar programmes at other universities in the Netherlands and abroad. The Meijers Criteria [16] are used as a reference for the general academic contents of the programme.

## A.2 Disciplinary pillars

### A.2.1 Typical topics in an EE curriculum

IEEE, the organisation of electrical engineers —with 425 000 members— has around 40 societies which cover many aspects of electrical engineering. Even for an EE programme it is impossible to cover the whole spectrum of electrical engineering and all its applications in the programme of one student. As a reference for the required EE courses we took the overview of courses in the

DSFR (2016) of the EE programmes in the Netherlands [113]. This overview is based on the requirements, formulated by IPENZ, ABET and ASIIN. The core of the BSc courses of EE is:

Core of EE courses

*Courses in grey are considered less relevant for CreaTe.*

- electrical networks
- dynamical systems
- analogue, digital and power electronics
- nano electronics
- device physics
- photonic integration
- telecommunication
- modelling
- measurement and control
- sensors and actuators (transducers)
- computer architecture
- programming
- embedded computers
- electrical energy systems
- electrical machines

### A.2.2 Typical topics in a CS curriculum

As a reference for the required CS courses we took the overview of courses in the DSFR (2019) of the CS programmes in the Netherlands (based on the table in chapter 4 of the report of the Association for Computing Machinery (ACM) and the IEEE Computer Society: 'Curriculum Guidelines for Undergraduate Degree Programmes in Computer Science' [114]). The core of the BSc courses of CS is:

Core of CS courses

*Courses in grey are considered less relevant for CreaTe.*

- algorithms and complexity
- architecture and organisation
- computational science
- discrete structures
- graphics and visual computing
- human-computer interaction
- security and Information assurance
- information management
- intelligent systems
- networking and communication
- operating Systems
- platform-based Development
- parallel and Distributed Computing
- programming Languages
- software Development Fundamentals
- software engineering
- system fundamentals
- social and professional issues

### A.2.3 DSFR of Industrial Design Engineering

As a reference for the required content in the area of Industrial Design Engineering (IDE) we took the building blocks mentioned in the DSFR of IDE. The IDE curriculum consists of the building blocks:

Building blocks of IDE

*Building blocks in grey are already covered elsewhere in this document.*

- Research design / Research through Design
- User Centred Design
- Product development / Design
- Engineering (Electrical, Mechanical, Software, engineering)

The following requirements for a graduate of IDE is relevant for Creative Technology as well:

- A university IDE graduate can realise new or modified artefacts, products or systems, with the aim of creating value in accordance with predefined needs and requirements.

### A.2.4 Typical courses on Entrepreneurship

Business Administration curriculum

As the reference for the typical *entrepreneurship* we used a typical *Business Administration curriculum*. We follow the definition of entrepreneurship defining it as the '*process of recognising, exploring and exploiting an opportunity*' (Venkataram, 1997). To this end, we teach our students necessary skills to recognise potential business opportunities (focusing on sustainable and social opportunities, besides economic ones) in any context. They also learn how to evaluate and exploit opportunities. Therefore, the entrepreneurship programme at CreaTe, includes:

- Lean start-up methodology and customer development
- Entrepreneurial mindset and competences
- Business models
- Industry analysis
- Strategy and innovation

- Sustainable and social entrepreneurship
- Entrepreneurial finances
- Entrepreneurial marketing
- Entrepreneurial funding
- Pitching a business idea.

## A.3 Advisory board

Advisory board

CreaTe has had an *advisory board* from its early days. They helped the programme initially to shape itself and position itself in the broad range of related programmes. The board consisted of a broad representation of various disciplines, and had an international orientation.

Over time, we discovered that the initial model was not optimal anymore: the programme had developed itself and obtained a rather strong position. The board members were not sufficiently involved or positioned to help the programme take the next step: establish itself further in the professional domain and obtain input from the professional domain: either from representatives of the application domains or from the academic perspective. Therefore, we started with a new board, with well-respected influential members coming from academia and various application domains. The new board has had a first meeting in the spring of 2020.

## A.4 Benchmark

We examined several programmes in the Netherlands and abroad with curricula which are similar (or seem to be similar) with our idea of Creative Technology. The most relevant ones are the following ones.

Programmes in the Netherlands:

BSc Industrial Design Engineering – TU/e [115]

- In the first year, students follow basic courses such as calculus, physics, data analytics, user, society and entrepreneurship basics as well as 'major' courses such as programming, electronics, (user-centred) design. Already in their first year the students can choose from a number of electives. In the second year, they go in depth into some of the areas and apply their knowledge in projects.
- The core of the programme is defined by five areas of expertise: creativity and aesthetics; technology and realisation; user and society; math data and computing; business and entrepreneurship.

BSc Psychology & Technology – TU/e [116]

- The structure is very similar to the ID programme with basic courses (calculus, data analytics for engineers, physics, design, USE: user, society, entrepreneurship). The 'major' courses include courses on technology and psychology. Students can also choose electives already in their first year. In the second and third years they need to choose from USE electives.
- Technology courses depend on a specialization. Already at the beginning, students need to choose one of the three specializations: ICT, Robotics or Living. During each year they will deepen into one of the three subjects.

Abroad we found more or less similar programmes at Auckland University of Technology (AUT), New Zealand and the Bachelor of Computer Science and Arts (BCSA), Carnegie Mellon University, USA

BSc Creative Technologies at the Auckland University of Technology (AUT), New Zealand [117]

- Core courses include programming, physical computing, introduction to Creative Technologies, research methods, problem solving methods, and projects that depend on the students' choices. Furthermore, students get to choose from a number of electives including new media, entrepreneurship and innovation, or interactive technology.
- The study is multidisciplinary and heavily project based. As stated on their website, students learn to express their "ideas in a variety of digital and physical media —whether it's through video, sound, mechatronics, games or smart object".

Bachelor of Computer Science and Arts (BCSA), Carnegie Mellon University, USA [118]

- BCSA is an intercollege degree programme which combines the strengths of the College of Fine Arts (CFA) and the School of Computer Science (SCS). This degree comprehensively melds technology and the arts, such as game design, computer animation, computer music, recording technologies, interactive stagecraft, robotic art and other emerging media.
- The curriculum has three main components: general education requirements, fine arts concentration requirements and computer science concentration requirements. Each student's course of study is structured so they can complete this rigorous programme in four years.

A comparative analysis shows that Creative Technologies from AUT, even though it has the same name, has less engineering (especially electrical engineering) focus that our programme. The BCSA programme is just a combination of Computer Science and Arts. It completely misses the link with Electrical Engineering.

The two programmes in Eindhoven, however, could be used as a reference to our programme. Both programmes focus on the interaction between (electrical) engineering, programming, user-centred design, and entrepreneurship. It looks that the load of each discipline is similar to the one in Twente.

Several of the programmes we considered put emphasis on the combination of programming, new media, design, innovation, entrepreneurship and art. What makes the programme at the UT unique is the —in comparison to the other considered programmes— relatively strong technological base in electrical engineering and computer science.

Physical Computing

This can be expressed by the term '*Physical Computing*'. "Physical Computing intersects the range of activities often referred to in academia and industry as *electrical engineering*, *mechatronics*, *robotics*, *computer science*, and especially *embedded* development." (Wikipedia, [119])

Some of the other programmes we reviewed are:

Master programmes in the Netherlands:

- MSc Game and Media technology (University of Utrecht)
- MSc Media Technology (University of Leiden)

Programmes abroad:

- BSc Creative Media at the University of Worcester, UK
- BSc Creative Media Technologies - University of Portsmouth – UK
- In Germany there are many (72) options to study Medieninformatik. These programmes focus on programming and web applications)
- MIT Design Lab, Boston, USA Offers related courses with emphasis on Design
- MSc Creative Technology at the University of the West of England, Bristol. A one-year master's programme combining computer science with the creative arts.

What most of these programmes have in common are the following topics:

- programming
- design
- creativity
- interactive media
- (sometimes) physical computing
- working in projects and teams
- entrepreneurship & innovation

## A.5 Companies started by graduates of CreaTe

Today the technical possibilities are almost endless. Advanced components are commercially available. Useful and just-for-fun products can be realised by cleverly combining these in a new design. In depth knowledge of e.g. electrical engineering components is not always necessary. Still we see the CreaTe graduates as engineers, which are, in terms of the UT's motto, able to make

HighTech-Human Touch

*High-Tech designs with a Human Touch*. The first generations of students have produced nice examples in their spin-off companies, demonstrating that our vision of starting such a programme was the right one.

One example is Homey. The basis for Homey was led in a second-year CreaTe project. The students Emile Nijssen and Stefan Witkamp used the idea of an advanced domotica device when they had to write a businessplan as part of their CreaTe study. This convinced them of the market potential. They started their own company, Athom, and raised the necessary funds via a Kickstarter project. At the time this was the most successful Dutch Kickstarter project ever, reaching its goal in about a day.

Homey by Athom

Homey is a product able to control many 'domotica' systems in your house. The idea behind homey is that any domotica protocol and hardware is supported, such that one single device can communicate with and control all kinds of systems. Homey has hardware that supports all kinds of protocols relevant for domotica applications. It has an attractive design and is supported by IOS and Android apps, as well as by an own Appstore which enables Homey to connect to all kinds of devices and services. From the website of Homey we cite the following text:

*"Use Homey to control all your devices at home from a single smartphone app. Homey connects to lots of different devices from different brands. This means you can control your lighting, TV, wireless socket switches, blinds, thermostat and stereo within the same mobile application. No more searching for remotes, no more switching applications. Easily turn on some nice music while adjusting the lights to fit the mood. Homey works with all popular wireless devices, including IKEA TRADFRI, Philips Hue, Osram Lightify, Mi-light, Nest, Tado, Honeywell evhome, SmartTVs (Samsung, LG and Philips) and all infrared-controlled TVs, Sonos, Heos, AUX-connected speakers, Somfy, Brel, Fibaro, Aeotec and LightwaveRF. This way, we make sure you can choose the best solution for all aspects of your home, while at the same time, you can control everything from a single app – through Homey."*

Homey by Athom

IMPULSE

CreaTe student Lefika Otisitswe is co-founder of IMPULSE. *IMPULSE* offers companies an easy way to let their customers compensate their $CO_2$ footprint by its Carbon Reduction Service.

Lefika Otisitswe
co-founder of IMPULSE

*"We provide Clarity on carbon emissions and engage consumers in your sustainability activities! IMPULSE provides organizations with a cost-effective and visible CSR strategy through our carbon reduction service. With our carbon reduction service, your supply chain is analysed to effectively identify and reduce the carbon intensive hotspots. In addition, for the unavoidable emissions, our compensation service gives your customers a unique opportunity, at checkout, to compensate for the exact carbon footprint of the products that they purchase and/or the delivery by paying a few cents extra. These consumer contributions are invested in projects that prevent future carbon emissions locally and internationally. That's how we make Every Day For The Future.*
*IMPULSE makes 'doing good' intrinsic to consumer behaviour by internalizing sustainability in the products that are offered. This way, we can satisfy the needs of the present without compromising the ability of future generations to meet their own needs."*

tinygiants

Tiny Giants

During their Creative Technology study at the UT, our former students and now best friends Arian Hohmann, Bart Brinkman, Sebastian Helmig, and Ivan Rinaldo de Wolf came up with the idea to create digital designs. Together, they enjoyed making creative content at home. They then found out they were doing quite well, had confidence and believed in themselves. Finally, they thought: "We should do this professionally!"
They then founded the company *Tiny Giants* during their study. "That turned out to be the best decision ever." Without a doubt, this creative company has now become a 'tiny giant' in the content industry and will only continue to grow and create beautiful things. "We are reaching a higher level, larger customers and bigger assignments, and we make a living through our passion".
Tiny Giants is a company, that delivers visualisations of architectural projects, 2D and 3D animations, 3D printing, Virtual and Augmented Reality presentations.

Video on Entrepreneurship and Tiny Giants [45]

Tiny Giants

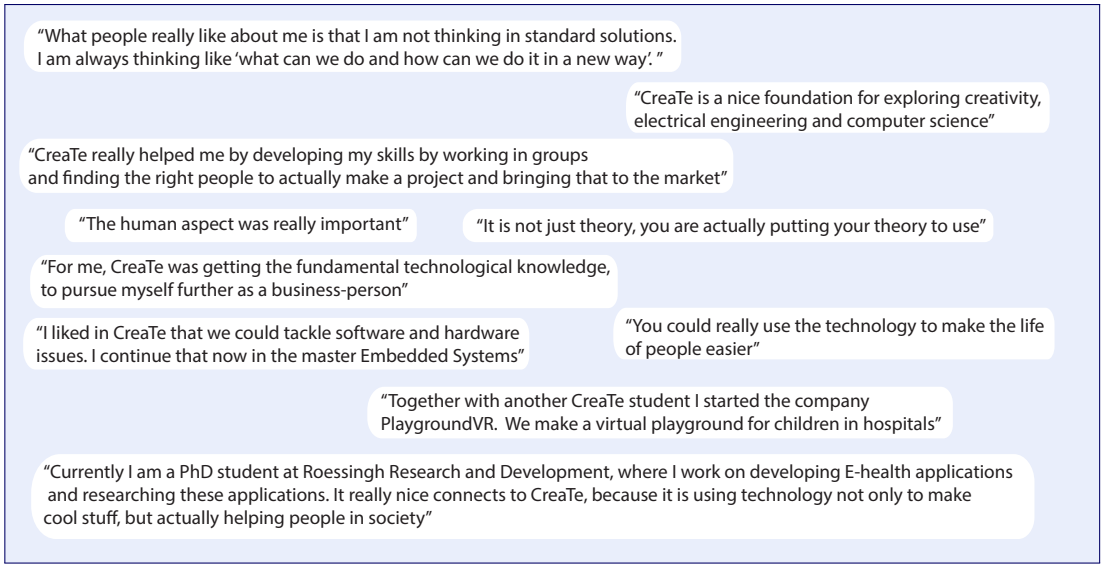
*"Tiny Giants has worked on many beautiful big productions for national and global companies and organisations. But the other big passion, besides commercial work, is creating meaningful content. Tiny Giants likes to support companies and organisations that have sustainable or social goals. For example, Tiny giants made content for Solar Boat Twente as a sponsor. They are also involved with the United Nations Global Compact (UNGC) in the Netherlands (GCNL), and the Sustainable Development Goals - Young Professional programme from GCNL." "We have learned a lot there about how we can use our creativity for sustainable and social purposes. We went back to Twente with this knowledge, to commit ourselves to ideas with impact."*

*"Creative Technology was the foundation of our newborn relationships as like-minded and creativity-seeking individuals becoming a united and powerful force of visual solutions!" - Tiny Giants*
*"Applying Creative Technology trained awareness of user's expectations and translating them into design solutions that address and satisfy them helped us to communicated on another level!" - Tiny Giants*

## A.6 How students experience(d) the programme

In a short movie [93], produced for a recent information meeting for prospective CraTe students, present and past students gave their opinions about the CreaTe programme. It was good to see that they experience(d) the programma as it was intended from the beginning. We summarise a few citations:

Students' impressions




### A.6.1 Meijers Criteria

Meijers criteria

Besides domain-specific knowledge and skills, graduates of CreaTe must master academic and professional skills as well as global competence. The generic academic criteria are well expressed in the so-called *Meijers criteria* [16]. These criteria have been formulated as a reference for the BSc and MSc programmes of the 3TUs. The seven areas of competence of the Meijers criteria are given in Table A.1. The full version of the Meijers criteria can be found in [16] and in a more compact form in [18].

**Table A.1** Seven areas of competence of the Meijers criteria (from [16], [18])

| | Topic |
|---|---|
| 1 | A university graduate is familiar with existing scientific knowledge, and has the competence to increase and develop this through study. |
| 2 | A university graduate has the competence to acquire new scientific knowledge through research. For this purpose, research means: the development of new knowledge and new insights in a purposeful and methodical way. |
| 3 | As well as carrying out research, many university graduates will also design. Designing is a synthetic activity aimed at the realisation of new or modified artefacts or systems, with the intention of creating value in accordance with predefined requirements and desires (e.g. mobility, health). |
| 4 | A university graduate has a systematic approach characterised by the development and use of theories, models and coherent interpretations, has a critical attitude, and has insight into the nature of science and technology. |
| 5 | A university graduate is competent in reasoning, reflecting, and forming a judgment. These are skills which are learned or sharpened in the context of a discipline, and which are generically applicable from then on. |
| 6 | A university graduate has the competence of being able to work with and for others. This requires not only adequate interaction, a sense of responsibility, and leadership, but also good communication with colleagues and non-colleagues. He or she is also able to participate in a scientific or public debate. |
| 7 | Science and technology are not isolated, and always have a temporal and social context. Beliefs and methods have their origins; decisions have social consequences in time. A university graduate is aware of this, and has the competence to integrate these insights into his or her work. |

### A.6.2 Consolidated Requirements for the BSc Creative Technology

In the previous sections we have identified:

- the essential topics in EE and CS curricula.
- the knowledge and skills with respect to design and entrepreneurship.
- the international perspective.
- the contents of similar programmes in the Netherlands and abroad.
- the advices of the Advisory Board.
- general academic criteria as given by the Meijers Criteria.

Based on this we come to the following requirements for graduates of Creative Technology.

**Table A.2** Consolidated Requirements

Consolidated Requirements

Graduates of CreaTe

1. fulfil the Meijers Criteria.
2. are T-shaped engineers, combining 'disciplinary' knowledge with the ability to apply more in depth knowledge to real-life situations. They are able to solve societal problems both individually and in diverse teams.
3. have a broad spectrum of knowledge in mathematics, physics, electronics, measurement and control systems, programming, design, user-centred design and human computer interaction

More specific, graduates in CreaTe have knowledge and skills in the areas:

4. Creativity and (self-)management
5. Programming and data science
6. Engineering and Smart Technology
7. Mathematics
8. Interactive Media
9. User Centred Design
10. Design: visual skills
11. Business and entrepreneurship
12. Art, Society and Ethics
13. Academic Skills.