TUM International Graduate School of Science and Engineering – IGSSE

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6th EUA-CDE Workshop
“Interdisciplinary Doctoral Programmes”
Turin, January 17-18, 2013
TUM. Profile

TUM. Departments

Center of Life and Food Science
Weihenstephan

Mechanical Engineering

Mathematics

Physics

Informatics

Electrical Engineering and Information Technology

Business Administration

Civil Engineering and Surveying

Sports and Health Science

TUM SCHOOL OF EDUCATION

Medicine

Chemistry

Architecture

TUM. Dimensions 2011

~ 31 000 Students, 32% Female Students, 16% Internat’l Students
~ 12 000 First-year Students
~ 5 140 Graduates
  475 Professors (incl. hospital)
~ 5 700 Scientific Staff Members (incl. hospital)

156 Degree Courses, >30 in English
911 Doctorates completed

~ 5 000 Publications in peer-reviewed journals
  19 ERC Grants 2008-11
  48 Humboldt Laureates 2006-11
  13 Nobel Prize Laureates
  13 Leibniz Laureates (DFG) since 1986
  4 Humboldt Professors

€1.1bn Total Budget (incl. hospital)
TUM. Milestones

1868: Founded by King Ludwig II
1901: Right to Award Doctorates
1905: Admittance of female students
       First female doctoral candidate
1957: First Neutron Research Reactor in Germany
1967: Department of Medicine, University Hospital
1999: Entrepreneurial University Constitution
2002: TUM Branch in Singapore (TUM. Asia)
2005: Institute for Advanced Study (TUM-IAS)
2006: TUM elected “University of Excellence”
2009: TUM Graduate School
2010: TUM University Foundation
TUM. Selected Nobel Laureates

- Heinrich O. Wieland 1927, Chemistry
- Hans Fischer 1930, Chemistry
- Rudolf L. Mößbauer 1961, Physics
- Ernst Otto Fischer 1973, Chemistry
- Klaus von Klitzing 1985, Physics
- Robert Huber 1988, Chemistry
TUM. Inventors, Engineers, Entrepreneurs

- Oskar von Miller
  Storage Power Plants
  Walchensee Power Plant
  German Museum

- Carl von Linde
  Refrigeration Engineering
  Linde’s Refrigeration Machines
  Air liquefaction

- Rudolf Diesel
  Combustion Engine Development
  Diesel Engine (MAN)

- Claude Dornier
  Aircraft Construction
  Sea Planes

- Willy Messerschmitt
  Aircraft Construction
  First Jet Plane Engine

- Heinz Maier-Leibnitz
  Neutron Research
  "Atom Ei"
Munich Metropolitan Region

Research Network

Industry Network
TUM. Partner Universities and International Locations

170 Partner Universities &
320 Erasmus Cooperations
IGSSE is the International Graduate School of Science and Engineering

- Initiate a paradigm shift in graduate education
- Provide structured research training
- Interlink existing PhD programs
- Bridge the gap between science and engineering
- Foster team-based, interdisciplinary research
- Enhance international collaboration
- Offer soft-skills training
- Give career orientation and promote social responsibility
- Attract the best doctoral candidates from around the world
- Prepare the way for the TUM Graduate School

- Individual doctoral thesis remains in the center of doctoral education.
- IGSSE creates a corporate environment with optimum conditions for outstanding research.
IGSSE Core Structure: Project Teams

- Small, flexible research groups combining
  - Natural sciences
  - Engineering
  - Medicine
- Bottom-up process
- Strict peer-review selection

2006-2012:
- 68 Project Teams established
- 199 doctoral candidates
Comprehensive Qualification Program

Goals:
- Subject-related & multidisciplinary qualifications
- Soft-skills training
- International orientation
- Responsibility towards society

Framework:
- Supervision agreement
- Double mentoring
- Family-supportive policy

Characteristics:
- 300 high-level courses
- Full flexibility of choice
- Individual and peer coaching
IGSSE Forum

TUM Off-Campus Science & Study Center
Raitenhaslach Monastery, Burghausen

- Annual networking event
- Scientific workshops
- Interdisciplinary exchange of ideas
- Renowned international guests from science, industry and society
- Discussion of pressing societal and cultural issues
- Festive graduation and awards ceremony
- Public visibility
IGSSE’s Global Dimension (2006-2012)

- 38% international doctoral candidates from 31 countries
- 120 long-term research stays abroad
- Papers at >600 international workshops/conferences
- >100 conferences, minisymposia and workshops organized
- >400 international guests
- Joint PhD programs, e.g. ParisTech, KAUST, NTU Singapore
Joint International Project Teams

22 teams (of 68) symmetrically funded by IGSSE and its partners (2006-2012)

<table>
<thead>
<tr>
<th>2+ Principal Investigators (professors)</th>
<th>TUM Chair Science or Engineering</th>
<th>Partner Chair Engineering or Science</th>
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<tbody>
<tr>
<td>Project Team Leader (postdoc/young researcher)</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>Doctoral Candidates 2 funded by TUM 2 funded by partner</td>
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<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>Master’s Students</td>
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- DTU Copenhagen
- ETH Zürich
- EPF Lausanne
- Stanford University
- Virginia Tech
- NUS Singapore
- Tsinghua University
- Wuhan University
- Fudan University
- University of Alberta
- KAUST
- …
TUM Graduate School (since 2009)

11 Thematic Graduate Centers incl. 3 in external cooperation with Helmholtz and Max Planck

Advisory and cooperation w/ TUM Institute for Advanced Study

13 Faculty Graduate Centers
Interdisciplinarity ... supervisor view

R. Burgkart

Head of Orthopaedic Research and Education
Clinic for Orthopaedic Surgery, Klinikum r.d. Isar, TUM
**major research areas**

**Biology** → cell (TE)
- Biologists, Chemists, Biophysicists

**Biomechanic** → implantat testing
- cell- and tissue characterisation
- mechanostimulation
- Engineers

**Technology** → imaging, navigation, robotics
- Informatics

**Integration**
- Health Professionals

Kessler
Bausch
Petry u.a.

Wall
Lindemann
Ulbrich
Winterm.
Lüth
Hirzinger
u.a.

Rank
Western.
Navab
u.a.

Burgkart et al. *Arthritis Rheum.* 2003
Eckstein, Burgkart et al. *Osteoarthritis Cartilage* 2006
new implant development ...

→ cell lab

osteointegration in vivo?

structured surface (SO)
- pore size 200 – 500 µm
- Porosität 45%

unstructured surface (UO)
- roughness Rt = 0.72 – 0.86 µm

+ Bioactivation
- RGD Peptides
- HA
- Plasmaaktivatio´n

Kessler TUM Chemistry
Westphal / ITEM Medical Engineering
Osteointegration in vivo?

titan implants

Biomechanic: Push-Out Tests:

Burgkart et al  S N Ceramic  2009
modeling and simulation

complex tissue characterisation

• 6 DOF robot-based biomechanical analysis
  challenge – real time steering: 55 Hz → 4000 Hz

cooperations:

Prof. Riener (LSR TUM) → seit 2005
ETH Zürich

Prof. Ulbrich, TUM
Osteotomy with the DLR MIRO surgical robot

Institute for Robotics and Mechatronics, DLR
Clinic of Orthopaedics and Traumatology,
Clinic of Oral and Maxillofacial Surgery,
Klinikum Rechts der Isar
der Technischen Universität München

MiroSurge, July 2009
IGSSE - Project

“Computational Steering for patient-specific surgery planning”

3 IGSSE Stipendiaten

cooperation with
Prof. Rank - Computation in Engineering
Prof. Westermann - Computer Graphics & Visualization

Dick, Georgi, Burgkart, Westermann EUROGRAPHICS 2009
Dick, Georgi, Burgkart, Westermann VIS 2009
viewpoint of a Principle Investigator (PI) / Supervisor

opportunities and challenges?
opportunities

„primary“ motivation for PI´s 2006:

• source of research funding (problem of traditional funding)

• topics very suitable for as well as basic as applied innovative research and „open“ themes

• because of IGSSE „laws“ clear project planning and determination of aims between disciplines before start (advantage for doctoral candidates and PI´s) → benefit for both sides: high interest to fulfill the proposed goals for the official IGSSE report (e.g. common presentations and publication)
Behavior of primary human osteoblasts on trimmed and sandblasted Ti6Al4V surfaces functionalized with integrin αvβ3-selective cyclic RGD peptides

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1Department Chemistry, Institute for Advanced Study and Center of Integrated Nanoscience, Freie Universität Berlin, Berlin, Germany
2Orthopedic and Trauma Surgery, Klinikum rechts der Isar, Technische Universität München, Garching, Germany
3Department of Obstetrics and Gynecology, Clinical Research Unit, Technische Universität München, Garching, Germany
4Chemistry Department, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia

*additional source of research funding
• topics very suitable as well as basic and innovative research and "open" themes
• because of IGSSE „laws“ clear project planning and determination of aims between disciplines (advantage for doctoral candidates as well as both sides: high interest to fulfill the project goals)

(official IGSSE report (e.g. common presentations and publication))

Figure 3. Binding of integrin αvβ3 to trimmed Ti6Al4V disks coated with RGD peptides (1 to 4) was measured using a modified ELISA. Peptides were dissolved in PBS and coated overnight at a concentration...
opportunities

motivation for PI´s after some years of IGSSE:

• financial support for retreats together with other research teams (e.g. 1 week in a hotel with intense work seminars) → new interdisciplinary and interproject stimulation

• the annual 3 to 5 day´s meeting in Raitenhaslach: extremely fruitful for new idea exchange and meeting so far unkown experts in the own university („what´s going on …)
problems/challenges

• project team leaders = successful post doc’s → interest to make career → high fluctuation of project team leaders

• then it was sometimes difficult to ensure time efficient project progress

• assure „continuity“ by PI’s and doctoral candidates
problems/challenges

- in medicine different **doctorial „culture“**:
  - *no payment*
  - *thesis before final exam parallel to studying*
  - „only“ *part time*
  - „lower“ *requirements (smaller work packages)*

potential conflict when comparing …

- doctoral candidates from biology, chemistry, engineering etc.
problems/challenges

- different research „culture“
  - science – engineering (basic vs. applied; publication vs. prototyp ….)
  - medicine – engineering/informatics (high impact original publication vs. high ranked IEEE abstract ….)

- different „language“
  - e.g. „simulation“: in medicine vs. engineering
problem €

€ ?

problem

journal ?
benefits beyond the IGSSE ….

- beside
  - doctoral theses
  - publications and presentations

→ research results were the basis for **DFG* grant** (now applied)
→ and 2 new projects in *IGSSE Focus Area „Biomaterials“* (2013)

* DFG = German Research Foundation
conclusions

- ...
- ...
- ...
- ....

- IGSSE = great promoter for inter-/multidisciplinarity
Coated Implantation Surfaces - Influence of RGD Coating in Combination with Surface Properties on the Adhesion Process of Osteoblasts
We investigate the influence of peptide coating and surface roughness

Cell pool with primary human osteoblasts
Surface structure of TiAl$_6$V$_4$ disks
RGD peptide (sequence, spacer, anchor) highly specific and selective for $\alpha v \beta 3$ integrin

Binding of integrins on peptide coated surfaces
Interaction of osteoblasts on peptide coated surfaces
RGD peptides are better accessible for integrins on smooth surfaces

![Graph showing absorption at 492 nm for different surfaces]

<table>
<thead>
<tr>
<th>Surface</th>
<th>Peptide amount per disk</th>
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<tbody>
<tr>
<td>Trimmed</td>
<td>6.4 ± 2.2 (pmol/cm²)</td>
</tr>
<tr>
<td>Matt finished</td>
<td>4.5 ± 0.5 (pmol/cm²)</td>
</tr>
<tr>
<td>Sandblasted</td>
<td>27 ± 12 (pmol/cm²)</td>
</tr>
</tbody>
</table>

Smooth surface vs. Rough surface
RGD peptides accelerate cell spreading on rough surfaces after 1 h

<table>
<thead>
<tr>
<th>Time</th>
<th>PBS (%)</th>
<th>Peptide 1 (%)</th>
<th>Peptide 2 (%)</th>
</tr>
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<tbody>
<tr>
<td>Rough surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td>5</td>
<td>97</td>
<td>77</td>
</tr>
<tr>
<td>3 h</td>
<td>96</td>
<td>100</td>
<td>95</td>
</tr>
<tr>
<td>Smooth surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td>11</td>
<td>76</td>
<td>41</td>
</tr>
<tr>
<td>3 h</td>
<td>92</td>
<td>96</td>
<td>94</td>
</tr>
</tbody>
</table>

W/o peptide on rough surface after 1 h

With peptide on rough surface after 1 h
Good friends & great network

Knowledge about other disciplines

**Why did I choose the interdisciplinary topic?**

Importance of speaking the same language

3 months at NJCBM

Support in writing papers

Going through up and downs together

Supervising and teaching other students

**Working in a team**

Get involved in things beyond PhD

**What was the benefit of my PhD within IGSSE?**

Medical research needs interdisciplinary

Maximilian & Luisa

All put on their pants one leg at a time – also in science

Would I do it again?

Of course YES
Future IGSSE Strategy

Continue in the spirit of multidisciplinarity and networking
Future IGSSE Strategy

Focus Areas as incubators for emerging research fields

Integrate PostDocs and MSc students

Include liberal arts and entrepreneurial training

Take advantage of alumni network

Reinforce and extend gender & diversity measures

Expand collaboration in Munich Metropolitan Region

“IGSSE@5 continents”

Broaden and stabilize financial basis
Future IGSSE Strategy

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“IGSSE@5 continents”

Broaden and stabilize financial basis
IGSSE@5 Continents

- Strategic partnerships
- Joint PhD programs
- 1/3 joint international IGSSE project teams with top-level universities
IGSSE Focus Areas

- Incubators for emerging research fields
- Strategic TUM research topics
- Bottom-up process
- High critical mass
- Peer-review

2012 Topic:
- Green Technology  
  (within EuroTech Universities)

Further Topics:
- Biomaterials – start January 2013
- Water Science and Technology – start April 2013
Conclusions and Lessons Learnt

1. Involve all University actors (Board, departments, administration and doctoral candidates) in the planning process (‘top-down & bottom-up’)
2. Draft clear vision and goals and start powerfully – program can be adapted and refined later on
3. Communicate well in all program stages
4. Be aware: Interdisciplinary research = high-risk $\rightarrow$ high-reward!
5. Focus on measures with direct benefit for doctoral candidates – rather than on perfect administration and processes:
   - International exchange
   - Interdisciplinary collaboration and networking
   - Soft-skills training including career orientation
6. Set general standards, but allow for flexibility w.r.t. individuals and fields of research
7. Create belonging and mattering
8. Provide adequate and sustainable funds