Inquiry- and Research-based Teaching in a Course on Model Checking

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State of the Art

- Model checking research connects theoretical and practical aspects
- New algorithms are often implemented inside well-known model checkers
  - In development for many years
  - Complex
  - Large code volume
  - High entry barrier

However

This is seldom taken into account by university courses, which often remain on the theoretical level.

State of the Art ...

Our course wasn't any better.

State of the Art ...

Learning objectives:

- Students can present and compare different techniques
- Students know common algorithms and can implement them
- Students can summarize selected literature and are able to criticize
- Students can write their own specifications and evaluate them

So obviously

A purely frontal lecture-based course is the way to go.

State of the Art ...

Oh boy was our course missing the point.

Major Shortcomings

- Learning results reduced due to missing hands-on experience
- Scope of thesis topics is limited, as students have not learned how to appropriately address practical problems
- Missing experience in project work, tool usage and working collaboratively
  - Students do not meet expectations from industry
  - Skills could be acquired en passant in a programming project

Course Redesign

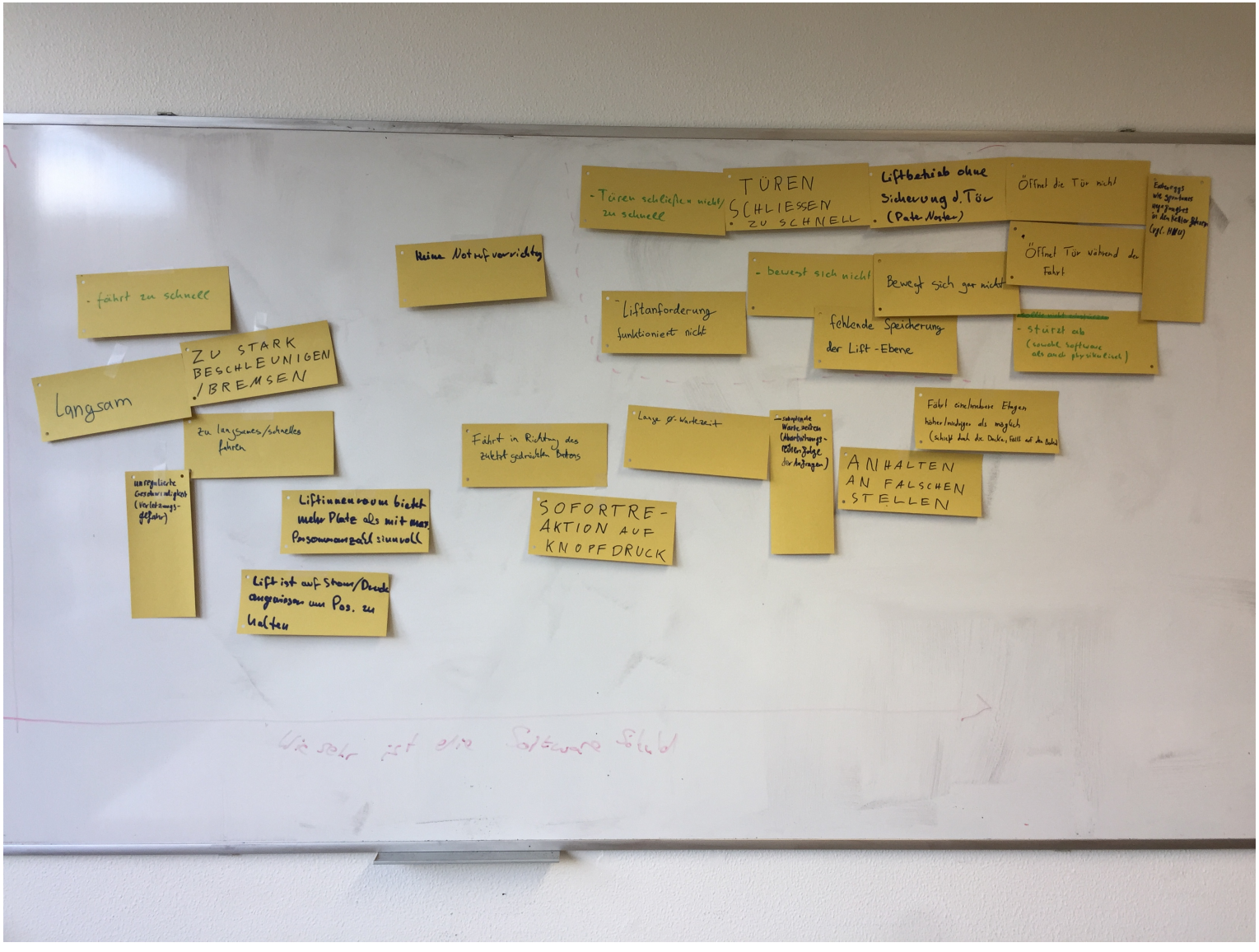
- High-level idea
  - Acquire the theoretical foundations by identifying and analyzing common software errors
  - Align these foundations with the body of knowledge
  - Design and implement a novel model checker as independently as possible
- Important aspects for success (Baron, et al.)
  - Selecting appropriate learning goals
  - Begin with problem-based learning before project work
  - Enable self-assessment and revision
  - Develop an atmosphere and social structures that support participation

Major Challenges

- Cognitive requirements are higher
  - Switch from knowledge reproduction to production
- Progression is less linear
- Individual workload is increased
  - Motivation and commitment has to be increased
- Research has to be controlled to avoid getting off track
  - As much freedom as possible, but guarantee intended learning outcomes
- Exams have to be prepared carefully to meet didactic requirements and exam regulations

Problem-based: Hazard Collection for Elevator

Problem-based: Sorted Hazard Collection

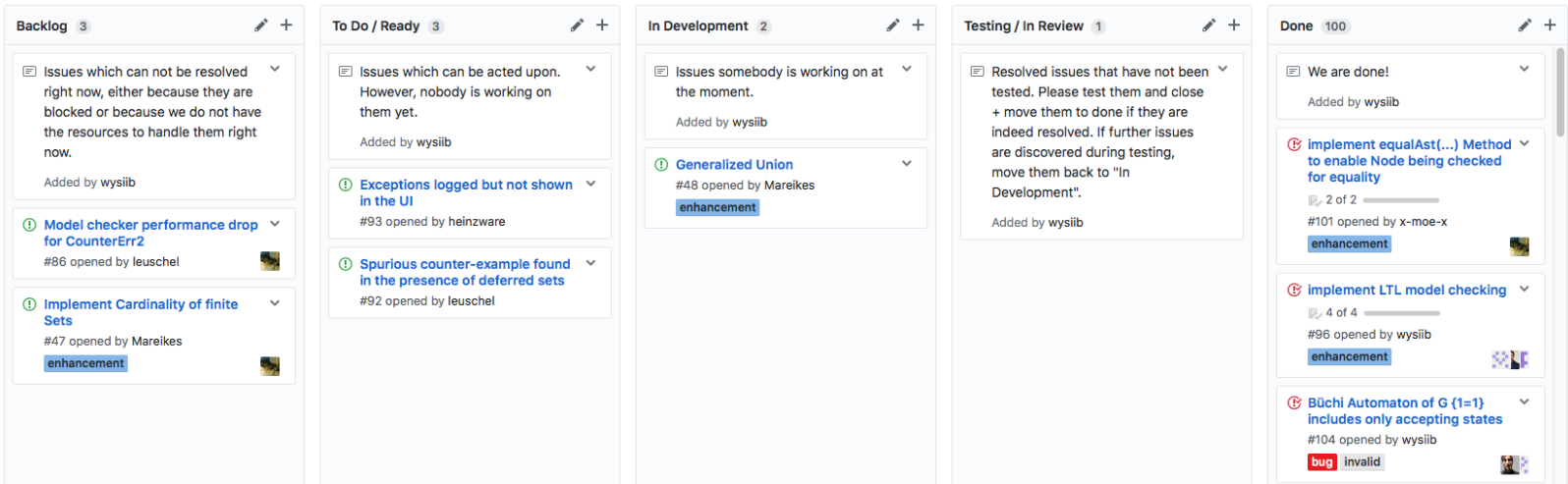


Course Sessions

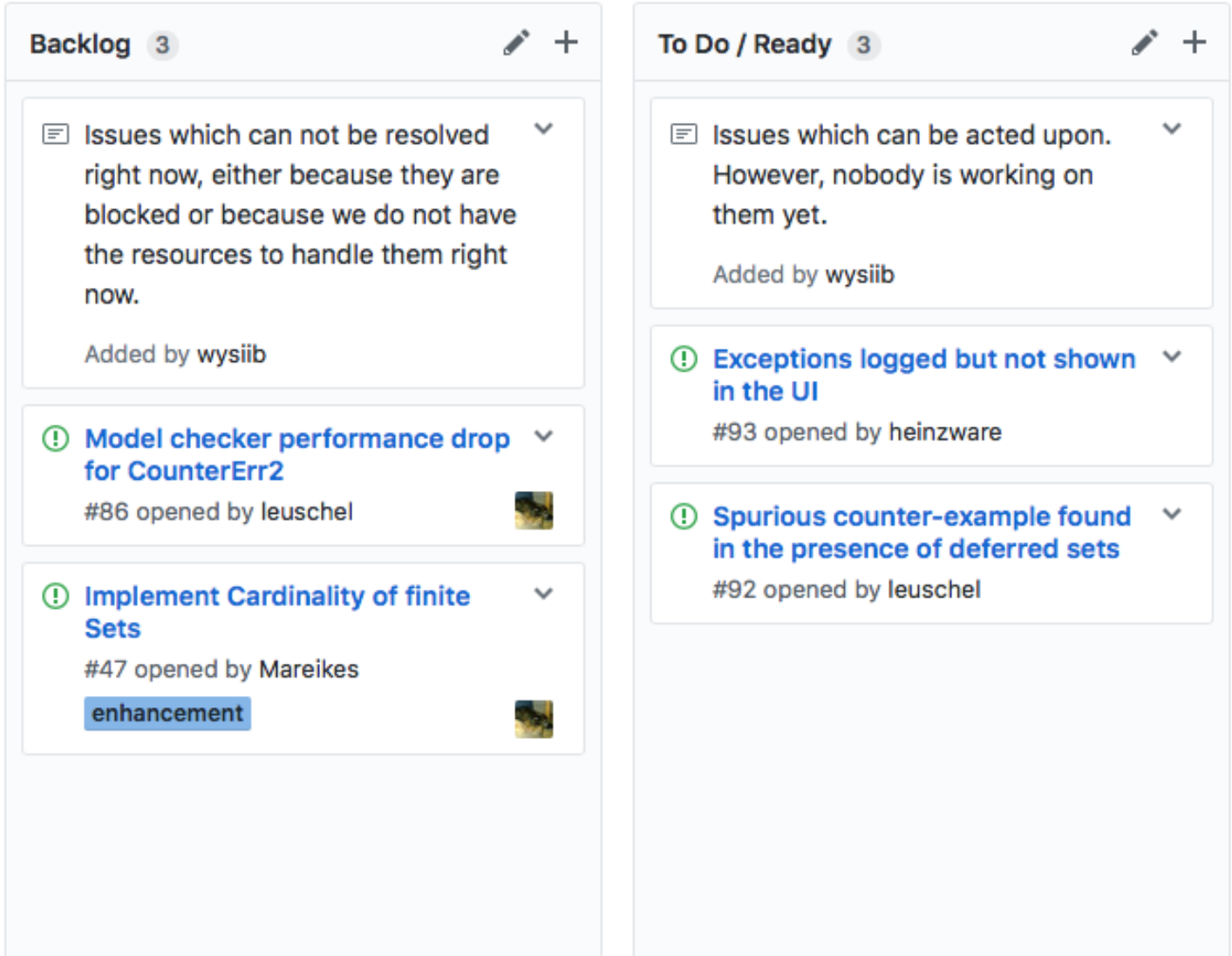
After problem-based introduction, iterate between

- Project management
- Implementation
- R&D sessions
- Reflection & evaluation sessions

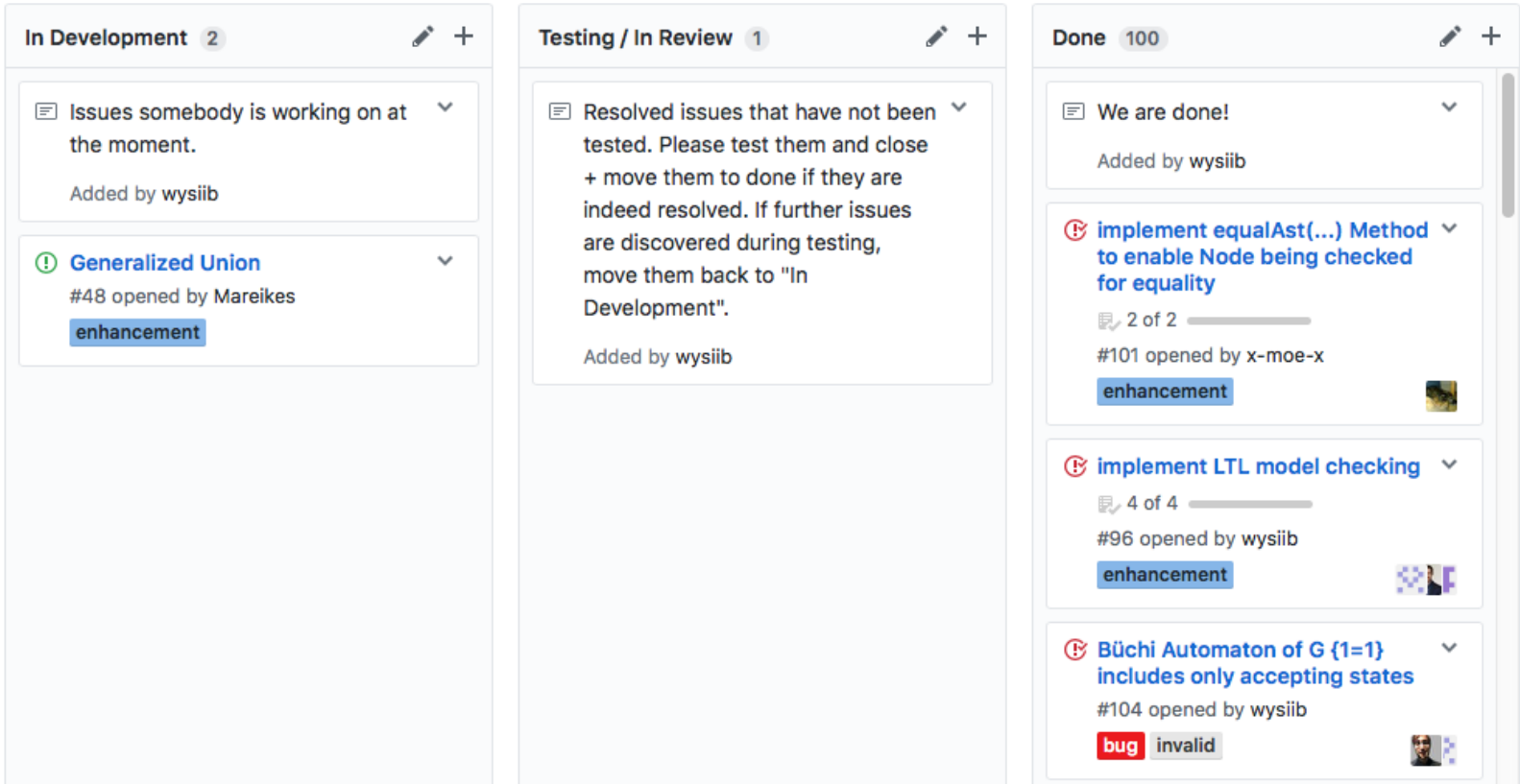
Project Management: Kanban



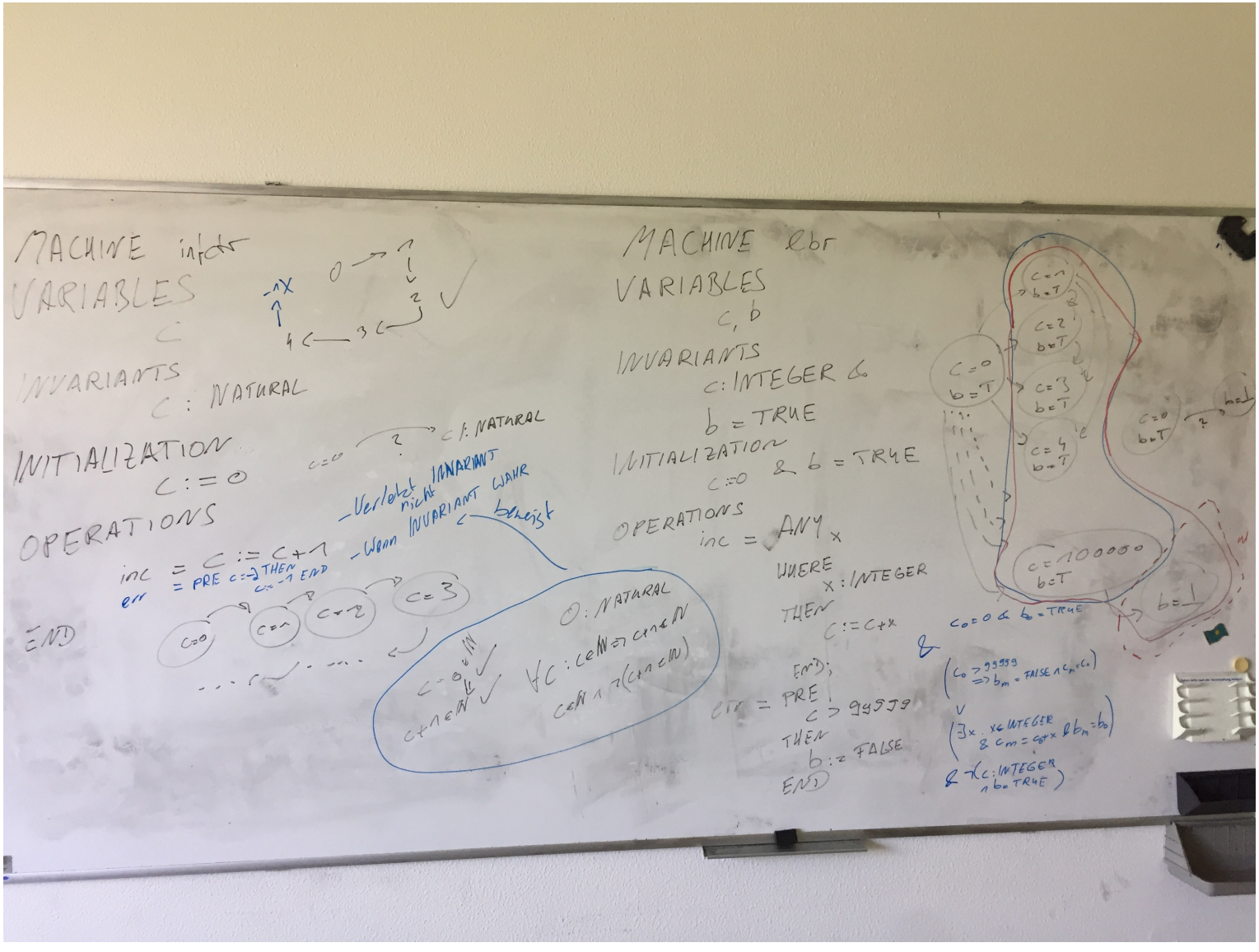
Project Management: Kanban



Project Management: Kanban



R&D: Algorithm Development



Course Evaluation

Different approaches to course evaluation

- Peer review by other teachers
- Direct student feedback
- Grades
- Learning data analytics

Grading

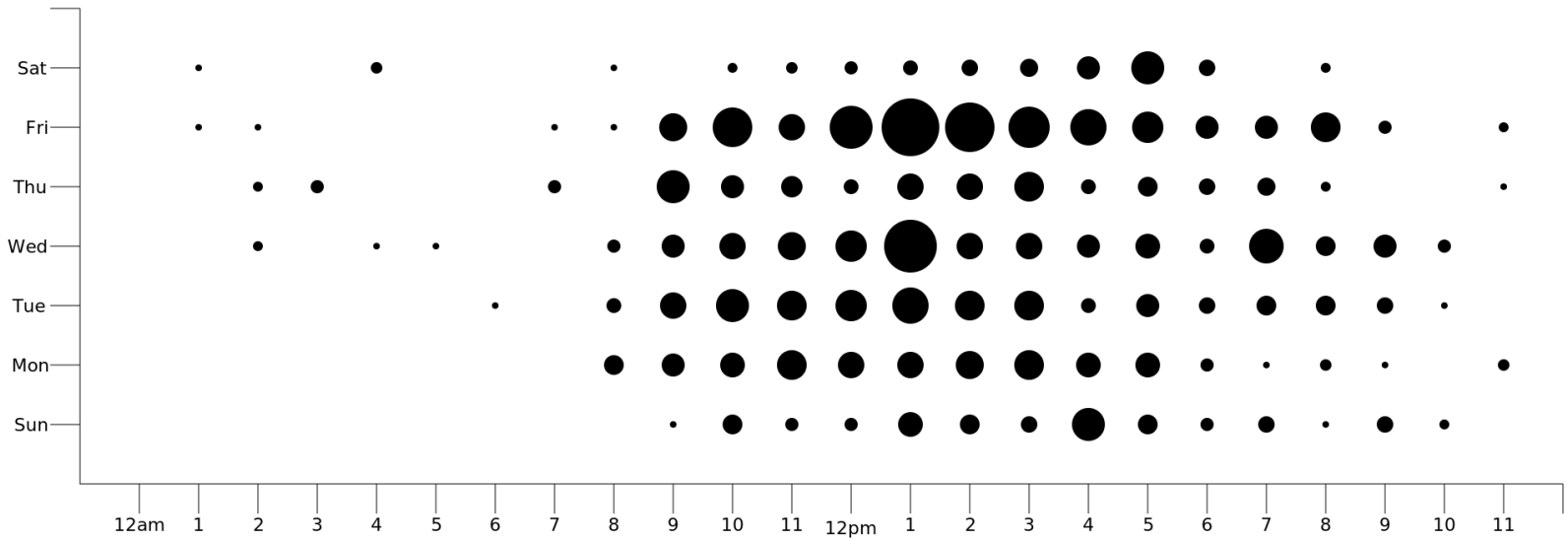
- Exam should measure both theoretical and practical aspects
- Ensure that grading complies with the examination regulations
- Improve constructive alignment (Biggs, 1996):
  - Formative part: constant participation documented using the Kanban board
  - Attitude, soft skills observed but hard to grade
  - Theoretical foundations by summative exam
- Combined exam verifies learning objectives!

Grades

	2014	2015	2016	**2017**	2018
# Students	2	5	7	**6**	5
∅ Grade	1.85	2.58	1.71	**1.28**	1.88

Evaluation: Additions and Deletions to Sources

Evaluation: Activity



Dissemination: SEUH Article

Experience Report on an Inquiry-Based Course on Model Checking

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Abstract

coming to grips with internal workings. In conse-

Last Step of Research: Publication

- Not part of the course, as we could not reasonable expect anything
- Still 3 students were interested
- Outside of curriculum:
  - Discuss publication process, peer review, etc.
  - How to write interesting paper (mostly following Peyton Jones)
  - Brainstorm possible topics and ideas
  - Writing, meetups for synchronization

One Question Remains

To what extent where our students doing relevant research?

Dissemination: Student Article

ECEASST

Writing a Model Checker in 80 Days: Reusable Libraries and Custom Implementation

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Abstract: During a course on model checking we developed BMoth, a full-stack model checker for classical B, featuring both explicit-state and symbolic model checking. Given that we only had a single university term to finish the project, a particular focus was on reusing existing libraries to reduce implementation workload.

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Conclusions

- Goals met
- Realization more hazzle-free than anticipated
- Highly motivating for students, immediate sense of relevance
- Scaling and proper knowledge propagation difficult

Summary

10 of 10, would teach that way again.

Thank you!

Any questions?