Applied Systems Sciences 1

Winter Semester 2026/27 · UNT.016UB · David Maier

A. Contact

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Office hours: by appointment via email

Course communication and organisational information are provided via Moodle.

B. Course information

Short description / course content

Content

This course is a project-oriented proseminar in the systems sciences. Its aim is to get to know central methods of the systems sciences and to apply them in practice. The methodological focus is on **agent-based modelling (ABM)**, embedded in project work using the programming language **Python**.

At the beginning of the semester, there is an introduction to systems thinking, consolidated together through exercises. Students learn to analyse real systems, carry out modelling cycles, and translate their results into code. Building on this, agent-based models are introduced as a tool for studying complex systems.

The seminar covers concept development, modelling, simulation, and interpretation of agent-based models. In addition, we discuss basic aspects of project work, systems analysis (tipping points, dynamics), and the sensible use of AI tools (e.g. GitHub Copilot).

The core of the course is independent project work in small groups, in which students develop, extend, and analyse an agent-based model. The projects focus on **social-ecological systems**, that is, systems in which people and their natural environment interact and shape each other. At the end of the course, the results of the project work are presented and discussed.

Prerequisites

- Successful completion of Systems Science 1 & 2
- Computational Basics (lecture + exercise)
- Basic programming skills in Python are expected

Course objective

Students gain a sound understanding of agent-based modelling (ABM) as a method of the systems sciences and are able to analyse, simulate, and critically reflect on complex systems using agent-based models. In particular, after this seminar they can carry out the entire modelling cycle independently, from conception through implementation to interpretation. In addition, students deepen their Python basics and learn to work with coding agents and the basics of software development with git.

Teaching and learning methods

The course is designed as an interactive proseminar with weekly sessions. It combines:

- lectures and live-coding sessions
- practical exercises
- discussions of methods, models, and applications
- supervised project work in groups
- presentation and discussion of results

Moodle is used to provide materials, for discussion (forum), and for organisational coordination. The course website additionally provides access to slides, PDFs, and resources.

Learning outcomes

After successfully completing the course, students are able to

- explain central concepts of the systems sciences (emergence, feedback, complexity, path dependence) and apply them to real systems
- describe and carry out the modelling cycle (purpose, system definition, decomposition, model building, analysis)
- describe the principles, strengths, and limitations of agent-based modelling
- design an agent-based model conceptually and implement it in Python
- critically discuss model assumptions, results, and limitations
- visualise and interpret simulation results appropriately
- present and discuss a project in a structured way
- reflect on the use of AI tools in the modelling process

Semester schedule

Session	Date	Time	Topic
1	Thu 01 Oct 2026	08:30 to 09:45	Course introduction: thinking in systems
2	Wed 14 Oct 2026	09:00 to 10:30	Systems, feedback and emergence
3	Thu 15 Oct 2026	08:30 to 09:45	Models, agent-based models and LLMs, then the setup lab
	Thu 22 Oct 2026	08:30 to 09:45	Cancelled, a video instead: the traffic model's code explained
4	Thu 29 Oct 2026	08:30 to 09:45	Working with git and GitHub
5	Thu 05 Nov 2026	08:30 to 09:45	From ODD to code: the traffic model
6	Thu 12 Nov 2026	08:30 to 09:45	**Quiz 1** Watching emergence
7	Thu 19 Nov 2026	08:30 to 09:45	LLM APIs from Python
8	Thu 26 Nov 2026	08:30 to 09:45	Project kick-off
9	Thu 03 Dec 2026	08:30 to 09:45	Tipping points and feedback, project work
10	Thu 10 Dec 2026	08:30 to 09:45	Preliminary work presentations (P1), part 1
11	Thu 17 Dec 2026	08:30 to 09:45	Preliminary work presentations (P1), part 2
12	Thu 07 Jan 2027	08:30 to 09:45	Sensitivity and validation, project work
13	Thu 14 Jan 2027	08:30 to 09:45	**Quiz 2** Supervised project work
14	Thu 21 Jan 2027	08:30 to 09:45	Code review, project work
15	Thu 28 Jan 2027	08:30 to 09:45	Final presentations (P2), part 1
16	Thu 28 Jan 2027	10:00 to 11:30	Final presentations (P2), part 2

Required reading

There is no single required reading. The cheatsheets and slides provided on Moodle and the course website contain the relevant theory and practical elements for the course. Literature is recommended by topic in connection with the sessions and made available via Moodle.

Recommended literature

Primary literature:

- **Mobus, G. E. & Kalton, M. C. (2015).** *Principles of Systems Science.* Springer.
- **Metcalf, G. S. et al. (Eds.) (2021).** *Handbook of Systems Sciences.* Springer.
- **Railsback, S. F. & Grimm, V. (2019).** *Agent-Based and Individual-Based Modeling: A Practical Introduction.* 2nd Edition. Princeton University Press.

Supplementary:

- Meadows, D. H. (1999). *Leverage Points: Places to Intervene in a System.* The Sustainability Institute.
- Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge University Press.
- Schelling, T. C. (1960). *The Strategy of Conflict.* Harvard University Press.

In addition, recommended literature is assigned by topic to the individual sessions on the slides, which are made available on Moodle before each session.

Useful websites, tools, and software

- **Editor:** Visual Studio Code (https://code.visualstudio.com/)
- **Version control:** Git + GitHub (https://github.com/)
- **AI assistant:** GitHub Copilot (free via GitHub Education)
- **Programming language:** Python 3.12+
- **Python documentation:** https://docs.python.org/3/
- **Course website:** asw1-ws26.dev.davidmaier.at
- **Moodle course:** link on Moodle

C. Assessment, workload, and grading

Overview

The assessment consists of five parts, from which the overall grade is formed:

Assessment	Points	When
Quiz 1 (basics)	15	session 6, Thu 12 Nov 2026
Quiz 2 (analysis and LLMs)	14	session 13, Thu 14 Jan 2027
Group project (model, presentation, discussion)	40	presentations in sessions 15 and 16
Individual final report	15	deadline to be announced
Participation	16	ongoing, contributions in sessions and on Moodle
Total	**100 points**	

The points are added up, and a weak part can be made up by the others, provided the total score is sufficient. One condition applies: the quizzes together must be positive, i.e. reach at least 14 of their 29 points. Otherwise the course is not passed, whatever the total score.

Grading scale

Grade	Points
1 (Excellent)	89 to 100
2 (Good)	77 to 88
3 (Satisfactory)	65 to 76
4 (Sufficient)	51 to 64
5 (Fail)	0 to 50

Excellent: You know the material covered excellently, including the details. You can also transfer your knowledge to similar tasks. You can also put your theoretical knowledge into practice, i.e. into code and models.

Good: You know the material covered well, including most details. You can often transfer your knowledge to similar tasks. You can mostly put your theoretical knowledge into practice.

Satisfactory: You know the material covered, though not in detail. You can partly transfer your knowledge to similar tasks. You can sometimes put your theoretical knowledge into practice.

Sufficient: You know the material covered adequately, though not in detail. You cannot transfer your knowledge to similar tasks. You mostly cannot put your theoretical knowledge into practice.

Fail: You hardly know the material covered. You cannot transfer your knowledge to similar tasks. You cannot put your theoretical knowledge into practice.

Workload

Activity	Hours
17 scheduled appointments (15 × 75 min + 2 × 90 min)	21 h 45 min
Independent study, preparation, and assessed work	53 h 15 min
Total workload	**75 h / 3 ECTS**

The allocation of independent study time will be revised with the course content.

Attendance / absences

This course is a **proseminar**, so **attendance** at the sessions is compulsory. If you have to miss sessions, talk to me. In exceptional cases, a substitute assignment is possible by arrangement.

Assessment in detail

Both quizzes are short tests on Moodle at the start of the session: multiple choice and short open questions, written individually. They are **closed book**: no notes, slides or other materials, and **no AI assistance**.

Quiz 1 **15 points, session 6:** Covers sessions 1 to 5: systems, feedback and emergence, models and the modelling cycle, ABM basics and when to use them, the roles of LLMs in this course, the ODD protocol, basic git and Python.

Quiz 2 **14 points, session 13:** Covers sessions 6 to 12: verification, random seeds, scenarios and replicates, parameter sweeps, calling LLM APIs (prompts, structured output, non-determinism), tipping points and hysteresis, sensitivity analysis and validation.

Group project (40 points): Students develop an agent-based model on given research questions in small groups (4 to 5 people). The assessment consists of:

- *Model quality* (20 points): research question, type of modelling, approach, code quality (documentation, modularity, error handling)
- *Final presentation & discussion* (10 points): clarity, structure, content, ability to discuss (10 to 15 min presentation + 5 min discussion per group)
- *Group report* (10 points): short report as a markdown file in the GitHub repository (5 to 10 pages) with research question, methodology, results, discussion

Individual final report (15 points): Individual reflection on your learning progress, your own contribution to the group project, and the use of AI tools (approx. 3 to 4 pages).

Participation (16 points): Active and productive participation in the sessions and contributions to discussions. Critical follow-up questions and questions that contribute to a deeper understanding of the material are valued particularly highly. If you have participated in a session, come to me at the end of that session so that I can award you the points. In addition, there will be 4 reading assignments, for each of which a short reflection must be submitted on Moodle (3 points each).

Group project: framework

- **Group size:** 4 to 5 people
- **Topics:** chosen from a given list
- **Focus:** agent-based modelling (other systems science methods are allowed)
- **AI tools:** sensible use of GitHub Copilot and similar tools is explicitly encouraged, but reflecting on their use is part of the assessment
- **Deliverables:**
  - GitHub repository with working code
  - short group report as a markdown file in the repository (5 to 10 pages): research question, methodology, results, discussion
  - final presentation (10 to 15 min)

Submission formats and deadlines

- **Presentations:** upload to Moodle as PDF or PowerPoint.
- **Code:** submission via GitHub repository
- **Group report:** a markdown file in the GitHub repository.
- **Individual final report:** submission as PDF on Moodle.
- **Deadline for group report & individual final report: tba**.

Use of AI for assessed work

The use of AI tools (e.g. GitHub Copilot, ChatGPT) for generating ideas, code support, revising texts, and research is explicitly **allowed and encouraged**, with the exception of the quizzes. A conscious and reflective use of AI tools is an explicit learning outcome of this course.

Responsibility for content, correctness, and independent work lies with the students. The individual final report is expected to include a reflection on the use of AI tools in the modelling process. During the final presentations, oral questions about the code are asked to check the students' understanding.

D. Participation

Good, active participation does not necessarily mean talking the most. There are many ways to foster dialogue, e.g. asking questions, talking with each other and not only with the lecturer, letting yourself be moved by others, and remembering that it is not about "being right" but about working together on topics, perspectives, and problems. Critical follow-up questions and questions that contribute to a deeper understanding of the material are particularly welcome.

Disability and diversity statement

If you need **support** during the semester because of learning difficulties, religious holidays or practices, disability or impairment, medical needs, or other reasons, please talk to me. If you have **questions or concerns** about the assessment or assignments, you can contact me by email at any time or talk to me in person before or after class.

My goal is to create learning environments that are appropriate, fair, inclusive, accessible, and stimulating.

If you need support beyond what I can offer, I encourage you to contact the services of the University of Graz, e.g. the Centre for Inclusive Studies (Zentrum Integriert Studieren), the Family Service, 4students, Psychological Counselling for Students, the Working Group for Equal Treatment Issues, your student representatives (StV), or the Austrian Students' Union (ÖH, see also the ÖH Helpline).

Sustainability statement

In line with our university's goals of promoting social, economic, and ecological sustainability, and in particular those of our faculty and the Department of Environmental Systems Sciences, I aim to integrate sustainable practices into this course. Digital submissions are preferred, and a critical and reflective approach to AI technologies enables a more conscious use of resources. I encourage all students to actively contribute to reducing waste, conserving resources, and promoting environmentally friendly behaviour.