HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI
MATEMAATTIS-LUONNONTIETEELLINEN TIEDEKUNTA
MATEMATISK-NATURVETENSKAPLIGA FAKULTETEN
FACULTY OF SCIENCE

Emmi Vuorio
Maija Aksela
Johannes Pernaa
The Unit of Chemistry Teacher Education,
Department of Chemistry,
University of Helsinki

SYSTEMS THINKING IN A CHEMIST'S WORK IN CONTEXT OF SUSTAINABILITY

INTRODUCTION

This study aims to showcase the systems thinking (ST) of chemists working on topics related to sustainability for a sustainable chemistry course for pre-service chemistry teachers. At the elementary level, ST uncovers interconnections and interactions within systems (Wiek et al., 2011). It spans the environment, economy, and society from local to global scales (Meadows & Wright, 2008; Wiek et al., 2011). Given that sustainability challenges traverse these domains and scales, ST offers a powerful lens to view chemistry, both as a scientific discipline and industry, in the context of sustainable development (Jegstad & Sinnes, 2015). To encapsulate the chemist's systems thinking, a concept map (CM) was developed, highlighting the integral elements and their interconnections derived from the interview. CMs effectively showcase interconnections and bridge diverse domains, supporting the representation of ST (Khajeloo & Siegel, 2022, Tripto et al. 2013). Further CMs are found to be a good tool for the assessment of ST.

METHOD

Data were collected through five semi-structured in-depth interviews with chemists. The research was conducted as a case study, aiming to uncover situations and contexts where individual chemists need to employ systems thinking.

RESULTS

This poster focuses on one case from interview with chemist 5 (C5).

Background information:

Professor of Analytical Chemistry and Circular Economy

Worked 20 years in the public sector in applied basic research

Context and situations of systems thinking:

- Circular economy applications
- Green Transition
- Recovery of critical materials
- Environmentally-friendly processes
- Perspective on supply security
- Expertise provision at the EU level and other scientific communication
- Role as a project supervisor
- Collaborations with companies and research institutes

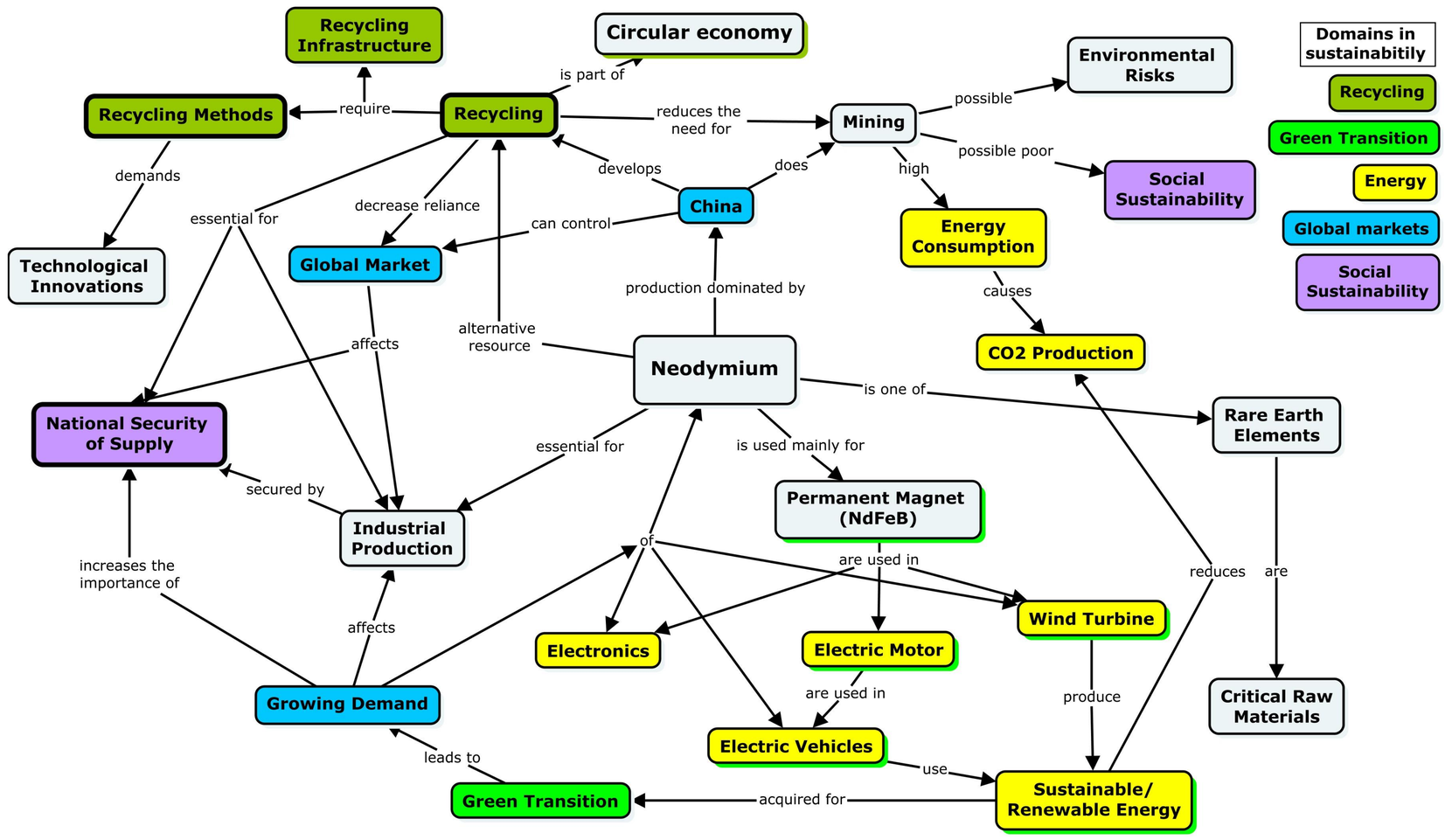

Figure: The concept map is compiled based on interview C5, using neodymium as an example. It displays the most essential concepts, their connections, and the domains of sustainable development, particularly when multiple related concepts from a single domain appear on the map.

C5 is pioneering a new recovery technique for metals, emphasizing its paramount importance for recycling rare earth elements (REEs) identified as critical and strategic raw materials (European Commission et al., 2023).

For the concept map compiled based on interview C5, neodymium, a prominent example of REEs mentioned during the interview, was chosen as a focal point. This CM illustrates the interplay among various elements, including the green transition, recycling methodologies, global markets, national supply security, and more. All these factors collectively shape the overarching sustainability concerns. For educational purposes, this model will be incorporated into the sustainable chemistry course. The instructional approach will progress from: 1. Generating a word cloud, 2. Developing a concept map, and 3. Identifying and color-coding different domains of sustainability present and their interrelationships.

DISCUSSION

Presenting a chemist's work toward a more sustainable solution through Systems Thinking (ST) can offer a valuable means to teach sustainability, ST, and the nature of chemistry as both a science and an industry. The Concept Mapping (CM) approach was chosen as it can serve as a tool for both learning and assessing ST. In a course where the objective is to introduce ST and sustainable chemistry, as well as to equip students with the pedagogical methods to teach these concepts, CM serves as a pivotal starting point. However, as Tripto and colleagues (2013) highlighted, CM might not be the optimal tool to elicit a student's understanding of patterns and capacity for temporal thinking. In the developed course, the more advanced ST skills will be evaluated using essay and project-based learning exercises

REFERENCES

European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Grohol, M., Veeh, C. (2023). *Study on the critical raw materials for the EU 2023 : final report*, Publications Office of the European Union. https://data.europa.eu/doi/10.2873/725585

Jegstad, K. M., & Sinnes, A. T. (2015). Chemistry teaching for the future: A model for secondary chemistry education for sustainable development. *International Journal of Science Education*, 37(4), 655–683. https://doi-org.libproxy.helsinki.fi/10.1080/09500693.2014.1003988

Khajeloo, M., & Siegel, M. A. (2022). Concept map as a tool to assess and enhance students' system thinking skills. *Instructional Science*, 50(4), 571–597. https://doi-org.libproxy.helsinki.fi/10.1007/s11251-022-09586-5

Meadows, Donella., & Wright, Diana. (2008). Thinking in systems: A primer. Chelsea Green Pub.

Tripto, J., Assaraf, O. B. Z., & Amit, M. (2013). Mapping what they know: Concept maps as an effective tool for assessing students' systems thinking. *American Journal of Operations Research*, 3(1A), 245–258. https://doi.org/10.4236/ajor.2013.31A022

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability science*, 6, 203–218. https://doi-org.libproxy.helsinki.fi/10.1007/s11625-011-0132-6