










DEVELOPING TEACHERS' INTERDISCIPLINARY EXPERTISE

DESIGN PRINCIPLES FOR TEACHER EDUCATORS

DEVELOPING TEACHERS' INTERDISCIPLINARY EXPERTISE

TRANSLATING THE OUTCOMES OF ARC DISCOVERY PROJECT "DEVELOPING INTERDISCIPLINARY EXPERTISE IN UNIVERSITIES"

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The authors are solely responsible for the content of the resource.

ACKNOWLEDGMENT OF COUNTRY

We acknowledge the tradition of custodianship and law of the Country on which the University of Sydney and the University of Queensland campuses stand. We pay our respects to those who have cared and continue to care for Country.

PURPOSE

The need to prepare teachers for interdisciplinary practices is well recognised in various policy documents and research literature (Markauskaite et al., 2023). For example, "The Alice Springs (Mparntwe) education declaration 2019" says that all young Australians should become successful lifelong learners who are "creative, innovative and resourceful, and are able to solve problems in ways that draw upon a range of learning areas and disciplines and deep content knowledge" (Education Council, 2019, p. 6).

The cross-curriculum priorities and general capabilities are integral parts of the National and NSW curricula (ACARA, 2023; NESA, 2023). For this, teachers need to have the expertise and confidence to design and implement integrative, interdisciplinary learning.

The NSW policy reform and innovation strategy "Education for a changing world" further expects that school leaders and teachers will have the skills and knowledge to best prepare students for lifelong learning in a changing world (NSW Government, 2019). Teachers need to be proficient in engaging in team teaching by rapidly—new technological tools, respond to diverse and changing student needs and develop their 21st-century skills. Teachers need to be proficient in engaging in team teaching by embracing multiple pedagogical approaches that connect existing subject knowledge to real-world contexts, teach collectively in new, more open school physical environments, adopt—sometimes very rapidly—new technological tools, respond to diverse and changing student needs and develop their 21st-century skills.

"The Australian professional standards for teachers" emphasises teachers' flexibility to draw on a broad range of professional knowledge and respond to diverse students' needs and teaching contexts (NESA, 2014/2018). Further, the report of the teacher education expert panel, "Strong beginnings" (Australian Government, 2023), recommends establishing the core mandatory content that every pre-service teacher should learn.

This core content draws on knowledge and evidence from different disciplinary fields that teachers need to be capable of integrating in diverse subject-specific teaching areas.

Teachers' interdisciplinary expertise—the capability to work with the knowledge that comes from different fields—is key to meeting these expectations.
The purpose of this resource book is to offer a set of design principles for integrating the development of different facets of teachers interdisciplinary expertise.

ABOUT THIS RESOURCE BOOK

This resource book aims to provide teacher educators with ideas, possibilities and practices for interdisciplinary teaching and learning. The resource is split into four main sections.

The first section presents an overview of the project, introduces interdisciplinary expertise within a teaching practice context, and presents an **ecological framework** that presents interdisciplinary teaching practices spanning three levels: micro, meso and macro.

The second section presents **design principles** across each level of the framework. The purpose of these design principles is to help design for teacher's interdisciplinary learning.

The third section presents an activity to develop a **model** that articulates what interdisciplinary expertise entails in a specific context, situating it in a broader context of the most important areas of teachers' interdisciplinary practices, needs for professional learning and enablers and barriers. The purpose of this activity is to offer a flexible but structured approach to understanding and enhancing teachers' interdisciplinary expertise.

The fourth and final section presents five **case studies** from in-service and pre-service teacher educators presenting interdisciplinary teaching and learning practices. These case studies provide ideas and opportunities for developing teachers' interdisciplinary expertise.

TABLE OF CONTENTS

OVERVIEW

The purpose of this project is to help prepare teachers for teaching in an increasingly interconnected, dynamic and unpredictable world, so that they can help their future students build on firm disciplinary foundations and integrate different areas of knowledge and ways of knowing. To help students respond positively and creatively to emerging challenges in workplaces and communities, schools will have to help them learn how to make connections across diverse knowledge domains, and how to apply what they know.

This project has two main aims:

1) to produce an overarching framework that articulates the main aspects of teachers' interdisciplinary expertise
2) to co-create a set of practical reusable design resources for embedding the development of teachers' interdisciplinary expertise in pre-service education and in-service professional development.

AIM 1 OUTPUTS:

- Markauskaite, L., Goodyear, P., Wrigley, C., Swist, T., & Mosely, G. (2023). Developing teachers' interdisciplinary expertise: Consultation paper. Sydney: The University of Sydney & The University of Queensland. DOI: 10.25910/kmyf-n324
- Markauskaite, L., Goodyear, P., Wrigley, C., Swist, T., & Mosely, G. (2023). Developing teachers' interdisciplinary expertise: Consultation report. Sydney: The University of Sydney & The University of Queensland.

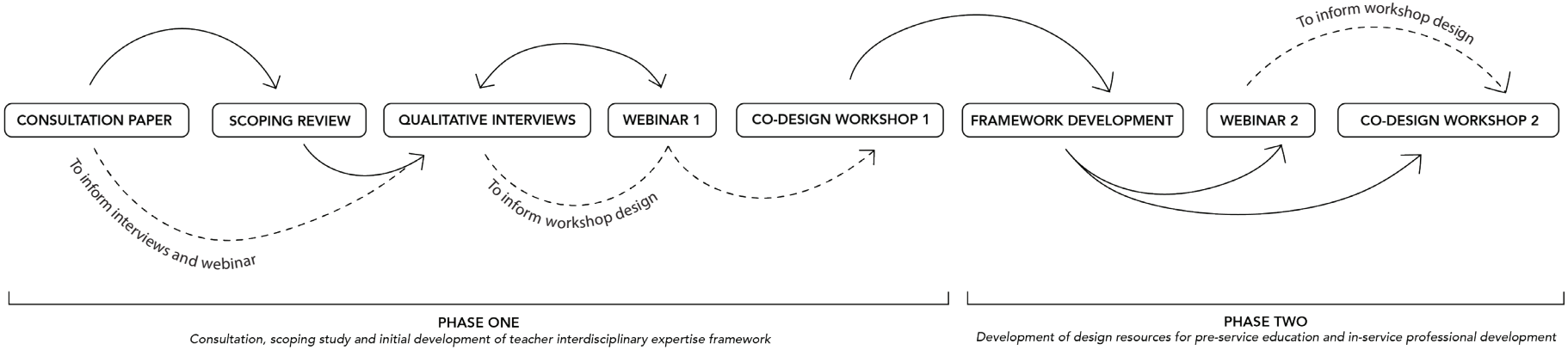
AIM 2 OUTPUTS:

THIS RESOURCE

CO-CREATED WITH IN-SERVICE TEACHERS AND PRE-SERVICE TEACHER EDUCATORS.

- Mosely, G., Markauskaite, L., Wrigley, C., Goodyear, P., with Currie, N., Levins, M, Reimann, P., Spence, N., Swist, T., Sutherland, L., & Yang, H. (2024). Developing teachers' interdisciplinary expertise: Design principles for Teacher Educators. (Ed.1). Sydney: The University of Sydney & The University of Queensland. https://doi.org/10.25910/raj1-bp41
- Swist, T., Markauskaite, L., Goodyear, P., Wrigley, C., & Mosely, G. (2023). Developing teachers' interdisciplinary expertise: An ecological framework for professional learning. Sydney: The University of Sydney & The University of Queensland. DOI: 10.25910/jr15-ts36

TIMELINE OF PROJECT ACTIVITIES



CO-DESIGN APPROACH

The resources in this book were developed using a co-design approach, which actively involves stakeholders in the design process to ensure that the outcomes are relevant and effective. This collaborative method harnesses the diverse perspectives of teacher educators, teachers, and other stakeholders to create comprehensive and practical solutions.

Our ecological framework for developing interdisciplinary expertise was shaped by the collective input of our participants and through case studies we illustrate practical applications of our interdisciplinary teaching approaches. This inclusive and iterative process was used to ensure that the resources are tailored to meet the needs and challenges of interdisciplinary teacher education in various educational contexts.

WHAT IS TEACHERS' INTERDISCIPLINARY EXPERTISE?

Teaching expertise refers to the teachers' capacities to perform productively, knowledgeably, and skilfully in relation to the encountered situation and context. It encompasses the relationship between teachers' personal attributes (knowledge, skills, dispositions, etc.) and a broader teaching activity system (shared goals, cultural, social, material, and knowledge resources, other people, etc.).

Interdisciplinary expertise accordingly, refers to the capacities for productive, knowledgeable, and skilful engagement in professional practices that involve multiple disciplines or other knowledge fields and foster connections between them. The terms "teachers' interdisciplinary expertise" and "teaching interdisciplinary expertise" are used synonymously. They refer to the relationship between the teacher's attributes and the larger system in which teaching activity is situated.

Markauskaite, L., Goodyear, P., Wrigley, C., Swist, T., & Mosely, G. (2023). Developing teachers' interdisciplinary expertise: Consultation paper (Ed. 2). Sydney: The University of Sydney & The University of Queensland.

TEACHERS' INTERDISCIPLINARY PRACTICES ARE MULTIFACETED

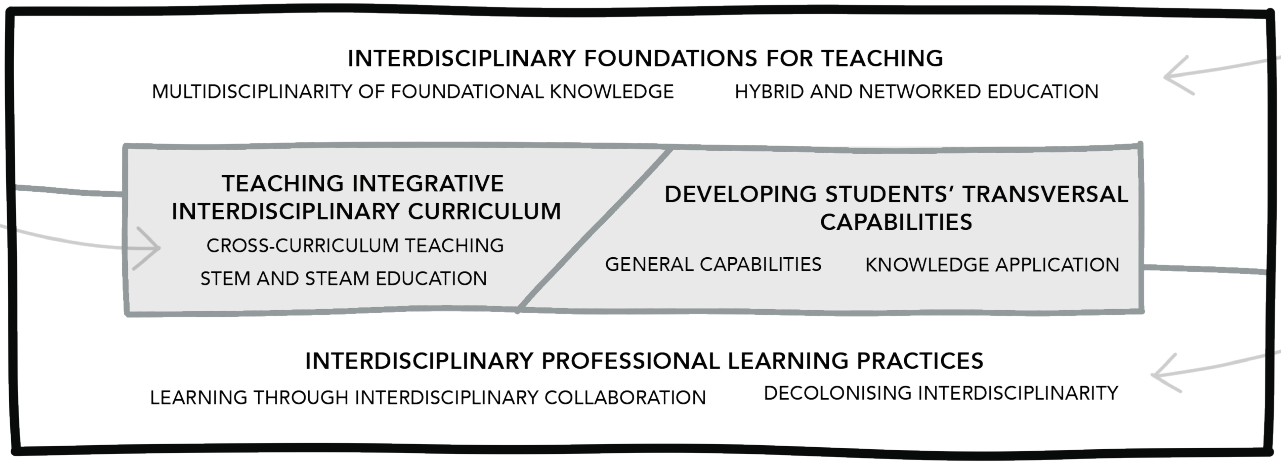
Teachers engage in a range of interdisciplinary practices which broadly relate to two intertwined aspects: 1) teaching and 2) professional learning.

Interdisciplinary teaching, such as *teaching integrative, interdisciplinary curricula and developing students' transversal capabilities*, is at the centre of teachers' engagement with interdisciplinarity

They are surrounded by a broader set of interdisciplinary professional learning practices related to the *interdisciplinary nature of foundational knowledge for teaching and the interdisciplinary nature of professional learning*.

Each aspect includes several facets described next.

MAIN FACETS OF TEACHERS' INTERDISCIPLINARY PRACTICES



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MAIN FACETS OF TEACHERS' INTERDISCIPLINARY PRACTICES

INTERDISCIPLINARY FOUNDATIONS FOR TEACHING

MULTIDISCIPLINARITY OF FOUNDATIONAL KNOWLEDGE

Integrating research advances from neuroscience, the developmental and learning sciences and subject knowledge into teachers' education is crucial. This approach ensures teachers understand how people learn, enabling them to apply this knowledge in diverse educational contexts. This foundational knowledge is essential for developing effective interdisciplinary teaching practices.

HYBRID AND NETWORKED EDUCATION

Developing teachers' digital capabilities is key in modern education. By integrating curriculum-related, ethical, and professional uses of digital technologies, teachers can enhance their pedagogical approaches and better prepare students for a digitally connected world.

Multidisciplinarity refers to an approach that involves drawing on knowledge from different disciplines while each discipline remains within its boundaries

DEVELOPING STUDENTS' TRANSVERSAL CAPABILITIES

GENERAL CAPABILITIES

Preparing teachers to teach 21st-century skills involves focusing on leadership, program design, learning environments, partnerships, and continuous improvement. This comprehensive approach equips teachers to foster essential skills in their students, such as critical thinking, communication, and collaboration.

KNOWLEDGE APPLICATION

Preparing teachers for programs that combine academic learning with relevant career and life experiences, such as Big Picture Education and Linked Learning, is crucial. These programs enable teachers to create meaningful and engaging learning experiences that connect academic content with real-world applications.

Transversal, in an educational context, refers to skills, competencies, or themes that cut across various subjects and disciplines. These are not confined to one specific field but are relevant and applicable in multiple areas, helping to integrate learning and create connections between different domains.

MAIN FACETS OF TEACHERS' INTERDISCIPLINARY PRACTICES CONT.

TEACHING INTEGRATIVE INTERDISCIPLINARY CURRICULUM

CROSS-CURRICULUM TEACHING

Teaching cross-curriculum priorities requires teachers to develop capabilities to introduce disciplinary concepts and processes in ways that enrich students' understanding of topics pertinent to today's society (e.g., sustainability).

STEM AND STEAM EDUCATION

Preparing teachers to teach STEM requires a focus on integrating and connecting STEM disciplines to solve real-world problems. This interdisciplinary approach ensures that students can see the relevance and application of STEM knowledge in everyday life.

INTERDISCIPLINARY PROFESSIONAL LEARNING PRACTICES

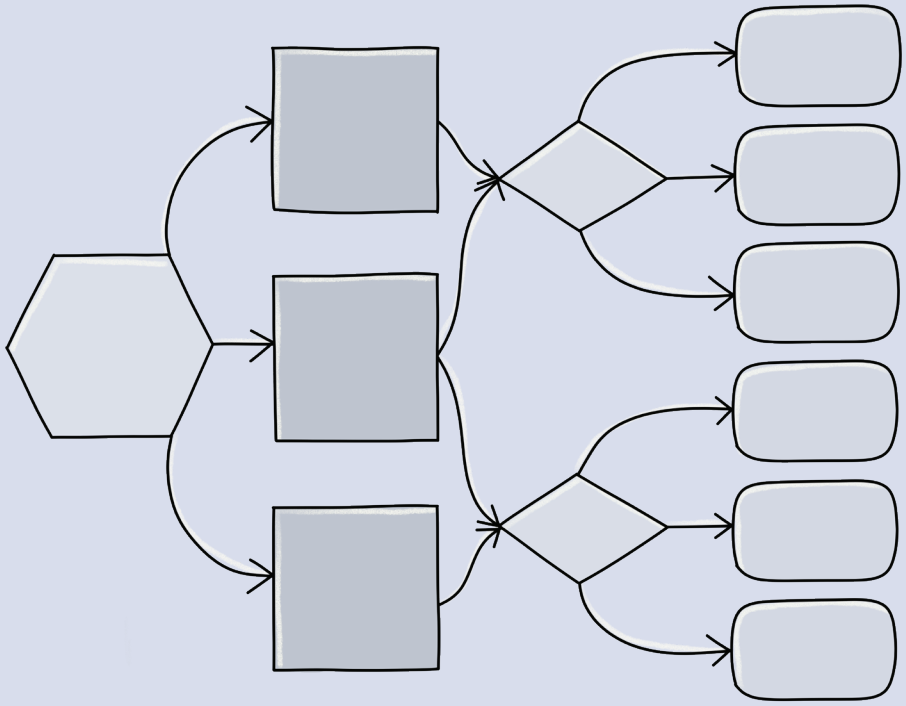
LEARNING THROUGH INTERDISCIPLINARY COLLABORATION

Creating opportunities for professional learning within interdisciplinary teacher communities is vital. Collaboration with experts beyond traditional disciplines, such as First Nation cultural educators, enriches teaching practice and broadens teachers' perspectives.

DECOLONISING INTERDISCIPLINARITY

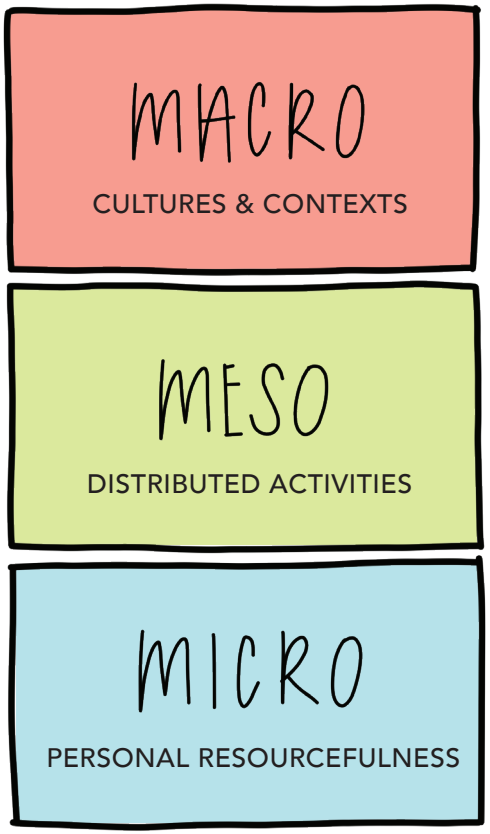
Developing teachers' understanding and commitment to equity and justice is achieved by embracing critical pedagogies. This approach encourages teachers to engage with contemporary disciplinary and interdisciplinary knowledge through the lens of social, environmental, and epistemic justice.

FRAMEWORK



ECOLOGICAL FRAMEWORK

Interdisciplinary teaching practices span different levels of the educational ecosystem—from individual teacher actions to collective activities within their immediate environment (e.g., classroom, school) to interactions with broader educational, social, political, economic, environmental, technological, and scientific contexts (e.g., curriculum, modes of knowledge production, job markets, climate change, and AI). Thus, interdisciplinary expertise for teaching involves capacities that span all levels—from teachers' personal resourcefulness (micro) to distributed activities (meso) and broader knowledge production systems, cultures, and contexts (macro).



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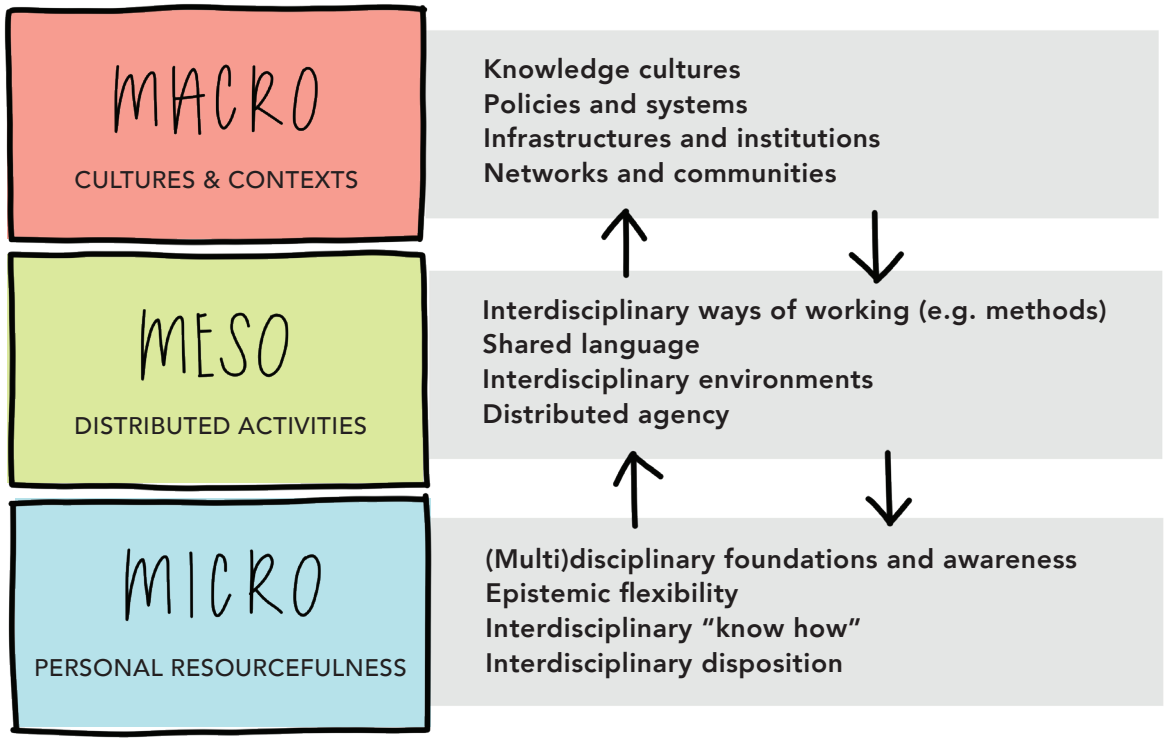
THREE LEVELS OF INTERDISCIPLINARY PRACTICES AND EXPERTISE



FOR FURTHER DETAILS SEE:

Swist, T., Markauskaite, L., Goodyear, P., Wrigley, C., & Mosely, G. (2023). Developing teachers' interdisciplinary expertise: An ecological framework for professional learning. (Ed. 2). Sydney: The University of Sydney & The University of Queensland. https://doi.org/10.25910/jr15-ts36

MICRO

TEACHERS' PERSONAL RESOURCEFULNESS

The **micro level** of the framework focuses on **teachers' personal resourcefulness,** which involves knowledge, skills, dispositions, and other personal resources to engage in interdisciplinary practices. At this level, teachers' interdisciplinary learning will focus on:

- **(Multi)disciplinary foundations and awareness**
- **Epistemic flexibility**
- **Interdisciplinary "know how"**
- **Interdisciplinary disposition**

Pre-service and in-service teachers should be encouraged to build their personal resourcefulness related to different facets of interdisciplinary practices by tailoring available learning professional opportunities to their needs and aims.

PERSONAL **INTERDISCIPLINARY DISPOSITION** TO ENGAGE IN INTERDISCIPLINARY TEACHING

SKILLS AND **"KNOW HOW"** ENACT INTERDISCIPLINARY TEACHING

(MULTI)DISCIPLINARY FOUNDATIONS IN RELEVANT AREAS SUCH AS SUBJECT EXPERTISE, AWARENESS ABOUT OTHER DISCIPLINES AND TRANSDISCIPLINARY DOMAINS (E.G., COMPLEX SYSTEMS, DESIGN THINKING)

EPISTEMIC FLEXIBILITY TO SWITCH BETWEEN DIFFERENT DISCIPLINARY AND OTHER WAYS OF THINKING

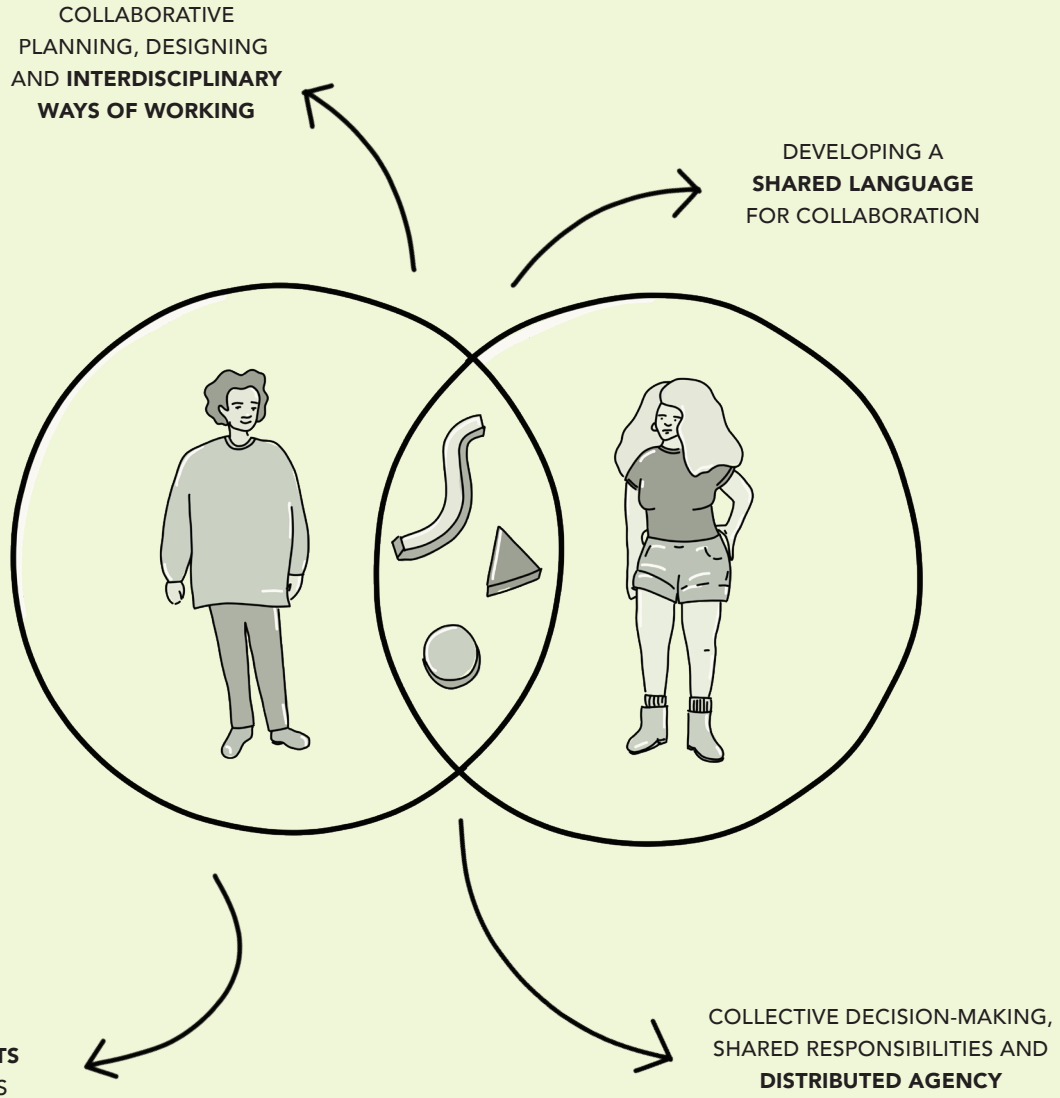
MESO

DISTRIBUTED ACTIVITIES

The **meso level** of the framework focuses upon **distributed activities**, which involve capabilities distributed among people and tools to carry out interdisciplinary work collectively in a setting. At this level, teachers' interdisciplinary learning will focus on:

- **Interdisciplinary ways of working (e.g. methods)**
- **Shared language**
- **Interdisciplinary environments**
- **Distributed agency**

Pre-service and in-service teachers should be encouraged to learn by engaging in diverse collective interdisciplinary practices within and beyond their local context.



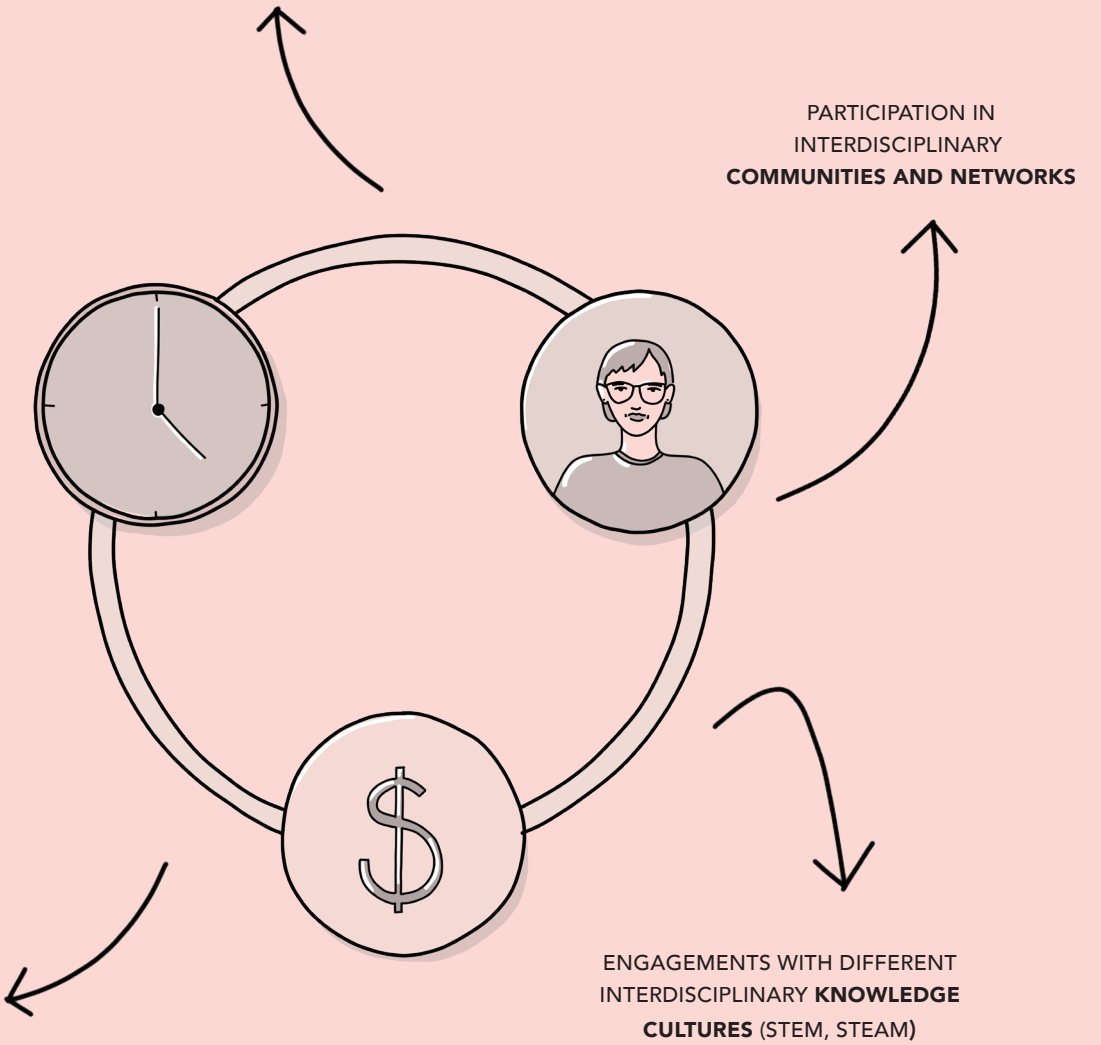
MACRO

SYSTEMS, CULTURES AND CONTEXTS

The **macro level** of the framework encompasses capabilities to navigate across, interact with, and shape various aspects of interdisciplinary practices that **extend beyond the immediate setting**. At this level, teachers' interdisciplinary learning will focus on:

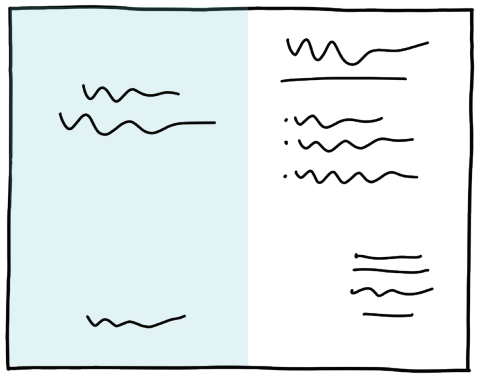
- **Knowledge cultures**
- **Policies and systems**
- **Infrastructures and institutions**
- **Networks and communities**

Pre-service and in-service teachers should reflect upon how these macro levels shape their interdisciplinary practices and how they could engage in practices shaping these levels.



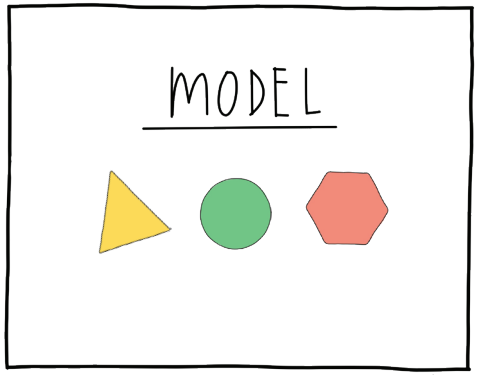
RESOURCES FOR TEACHER EDUCATORS

LAYOUT OF RESOURCES



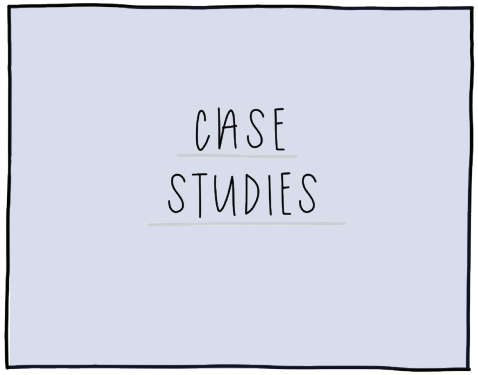
DESIGN PRINCIPLES

12 **design principles** to help you design for interdisciplinary teaching and learning in your context



DEVELOP YOUR OWN MODEL

Create a **model** that articulates what interdisciplinary expertise entails for your context



CASE STUDIES

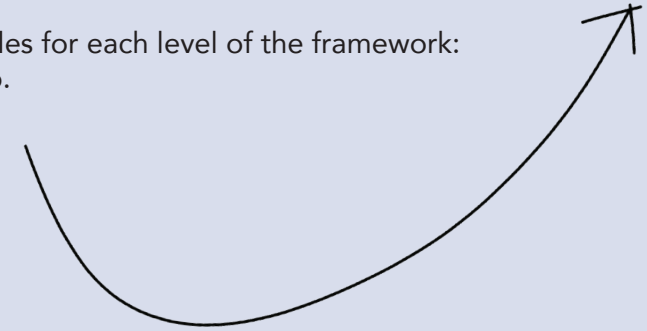
5 **case study** examples of interdisciplinary expertise development resources

DESIGN PRINCIPLES FOR INTERDISCIPLINARY TEACHING

The following section presents design principles to help you design for teachers' interdisciplinary learning in your context.

These principles are not meant to be exclusive or followed in a strict sequence; rather, they should be considered together and adapted to fit your specific goals and context. They are meant to give you ideas to build on and adapt to your unique setting and circumstances.

We present four principles for each level of the framework: micro, meso, and macro.



MICRO

- Dispositions
- Time
- Ethics
- Empathy

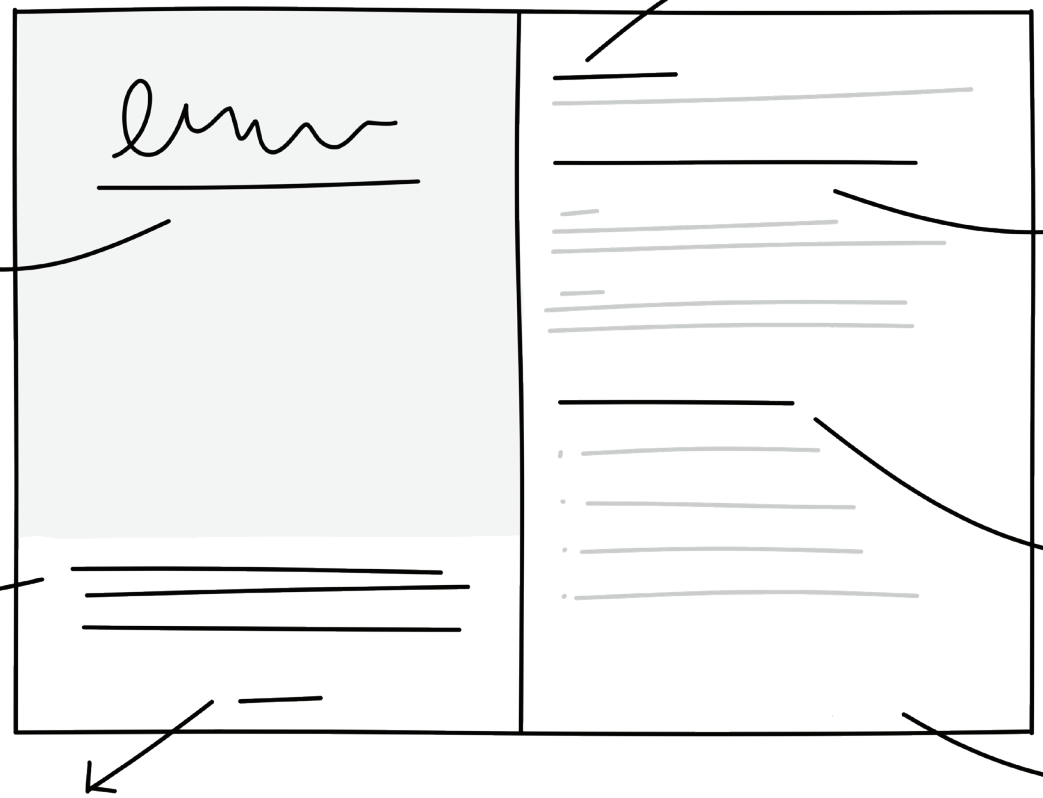
MESO

- Connecting
- Lesson Co-planning
- Glossary
- Mentors

MACRO

- Leadership
- Collaborative Culture
- Communities of Practice
- Institutional Support

LAYOUT OF PRINCIPLES



PURPOSE

The main objective of the principle and what it aims to achieve.

CONSIDERATIONS FOR USE

Key considerations when implementing the principle in the classroom or school setting. Each consideration includes an example.

ACTIVITY IDEA

An activity idea that helps teacher educators understand and use the principle for classroom implementation in teacher professional learning contexts.

VISUAL

Some principles provide a visual aid that support the activity.

TITLE

The name of the principle.

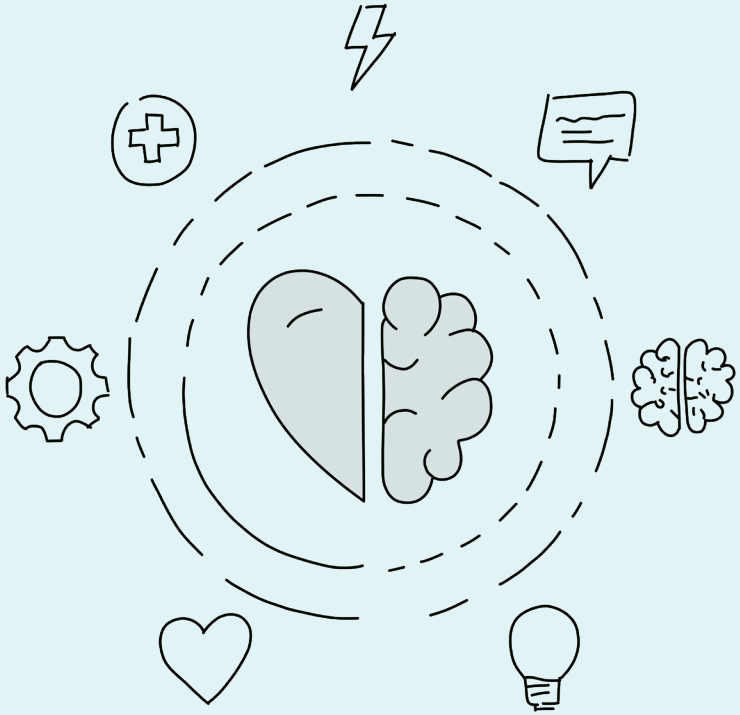
DESCRIPTION

A brief explanation of the principle, highlighting its importance and relevance teachers' interdisciplinary expertise and learning.

FRAMEWORK LEVEL

Micro, Meso or Macro.

DISPOSITIONS



Developing interdisciplinary dispositions is critical for effective teacher interdisciplinary work. This includes being open-minded, collaborative, agile, and reflective. These dispositions help teachers navigate the complexities and challenges of working across disciplines.

MICRO

PURPOSE:

To cultivate the dispositions (including attitudes and behaviours) necessary for successful interdisciplinary teamwork.

CONSIDERATIONS FOR USE:

Open-mindedness: Encourage teachers to be receptive to ideas from other disciplines. Example: Promoting active listening and respectful discussions.

Collaboration: Foster teacher teamwork and collective problem-solving. Example: Using team-building exercises and joint professional learning strategies.

Agility: Help teachers develop the attitude and ability to overcome setbacks and to look for solutions to challenges. Example: Using agile structures to foster collaborative, adaptive ways of working aiming to respond effectively and collectively to challenges.

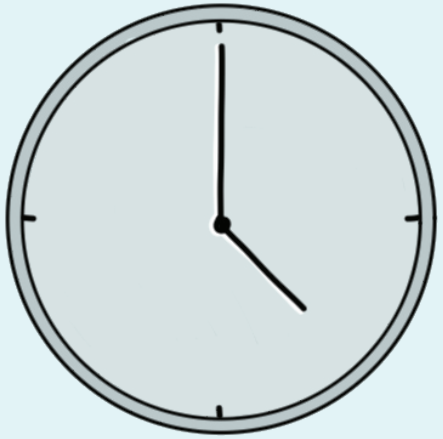
Reflection: Encourage regular reflection on their learning process and outcomes. Example: Journaling or group debrief sessions.

ACTIVITY IDEA: COLLECTIVE REFLECTION ON INTERDISCIPLINARY COLLABORATION AND RESPONSES TO CHALLENGES

1. Have teachers' choose a reflection method which could be an online journal.
2. After interdisciplinary collaborative lessons, encourage teachers to take some time to write about their experiences. Focus on the following:
   - What worked well in this session
   - Challenges they faced
   - Strategies they used to overcome these challenges
   - Insights or new ideas gained
3. Periodically, organise group meetings to discuss these reflections.
4. Discuss common themes and necessary changes in response to current challenges.

Note: This activity could be extended by having teachers discuss their reflections and debate why these dispositions and interdisciplinary teaching are needed.

TIME



Teachers often struggle to find the time to integrate interdisciplinary approaches into their busy schedules. The demands of curriculum coverage, lesson planning, assessments, and administrative tasks can leave little room for the additional effort required to design and implement interdisciplinary lessons. Helping teachers to learn productive strategies for addressing time constraints is crucial to making interdisciplinary teaching more feasible and effective for teachers.

MICRO

PURPOSE:

Help teachers find practical strategies for incorporating interdisciplinary approaches within the constraints of a busy teaching schedule.

CONSIDERATIONS FOR USE:

Collaborative Planning: Partner with colleagues to co-plan interdisciplinary lessons, sharing the workload. Example: Teaming up with a science teacher to integrate environmental science into a English unit.

Small Steps: Start with small interdisciplinary activities that require minimal extra time. Example: Incorporating a brief maths-related exercise into a history content lesson.

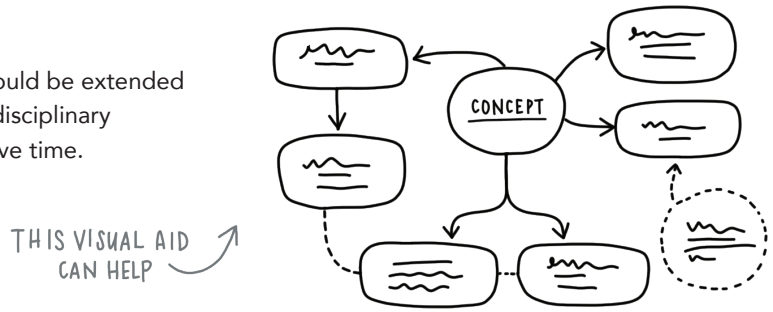
Time Management: Use effective strategies to streamline lesson planning and administrative tasks. Example: Setting aside dedicated time each week specifically for interdisciplinary planning, use templates to guide joint lesson planning

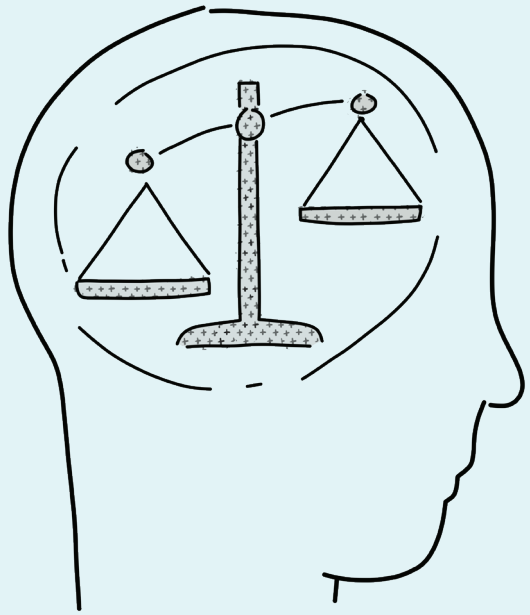
Student Involvement: Learn to engage students in the planning process to create interdisciplinary projects, saving preparation time. Example: Allowing students to choose project themes that combine subjects they are studying.

ACTIVITY IDEA: QUICK INTEGRATION BRAINSTORM

1. Provide teachers with a simple template to brainstorm interdisciplinary connections in their current curriculum.
2. Encourage teachers to identify one or two themes that could be easily integrated with their main subject.
3. Ask teachers to come up with short, 10-15 minute activities that link these subjects.
4. Discuss these ideas in small groups, providing peer feedback and additional suggestions, including for joint lessons.
5. Implement one of the brainstormed activities in the classroom and reflect on its effectiveness.

Note: This activity could be extended to discuss how interdisciplinary teaching can help save time.





Interdisciplinary ethics involves cultivating an awareness and consideration of ethical principles in all aspects of interdisciplinary teaching and learning. For interdisciplinary educators, this means ensuring that diverse perspectives are respected, and promoting integrity and fairness in collaborative work. This helps teachers navigate complex teaching problems with a strong moral compass.

MICRO

PURPOSE:

To integrate ethical considerations into teacher interdisciplinary teaching and learning.

CONSIDERATIONS FOR USE:

Ethical Discussions: Incorporate discussions on ethical issues related to interdisciplinary topics. Example: Debating the ethical implications of technological advancements in medicine.

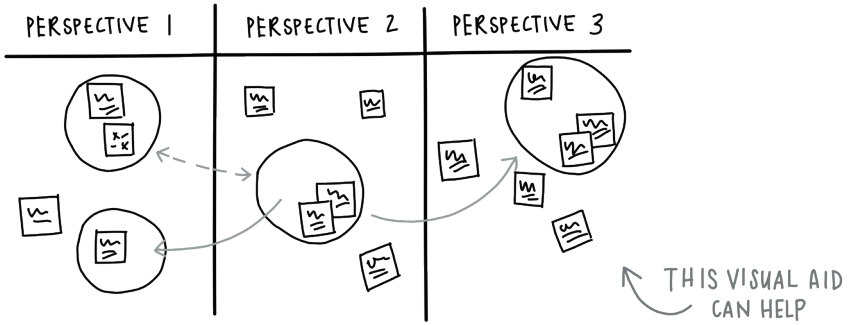
Diverse Perspectives: Ensure that all voices and viewpoints are included and respected. Example: Encouraging students to explore cultural and social implications of scientific research.

Integrity and Fairness: Promote honesty and fairness in all collaborative efforts. Example: Setting clear guidelines for group work to ensure equitable participation and credit.

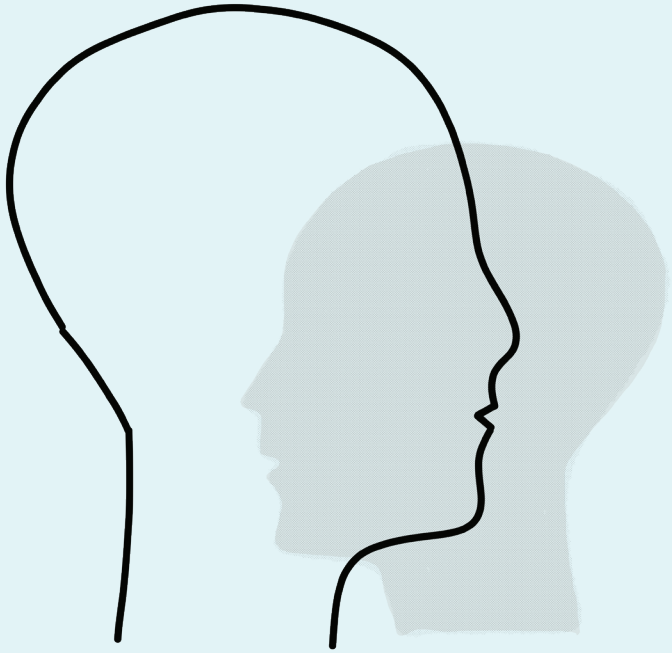
Real-World Ethics: Connect teachers' learning to real-world ethical dilemmas. Example: Case studies examining ethical decisions in environmental policy-making.

ACTIVITY IDEA: EXPLORING ETHICAL DILEMMAS

1. Present teachers with a real-world case study involving an ethical dilemma that intersects multiple disciplines.
2. Divide teachers into small groups and assign each group a role or perspective to represent.
3. Each group discusses the ethical implications from their assigned perspective and proposes a resolution.
4. Groups present their findings and solutions to other teachers. Facilitate a discussion to compare different approaches and highlight key ethical principles.



EMPATHY



Empathy in education involves understanding and valuing the feelings, perspectives, and experiences of others. For interdisciplinary teachers, fostering empathy helps them and their students appreciate the human side of various disciplinary and other perspectives and how they intersect. It encourages compassionate and inclusive learning environments, where students are more engaged and motivated to collaborate.

MICRO

PURPOSE:

To cultivate teachers' empathy and understanding in interdisciplinary teaching and learning.

CONSIDERATIONS FOR USE:

Perspective-Taking: Encourage teachers to see things from others' viewpoints. Example: Role-playing activities where teachers assume the roles of professionals from different disciplines.

Inclusive Practices: Ensure that all teachers feel valued and included in discussions and projects. Example: Creating group norms that promote respectful listening and sharing.

Emotional Intelligence: Teach teachers to recognise and manage their own emotions and those of others. Example: Incorporating activities that develop skills in emotional regulation and empathy, particularly respecting unfamiliar perspectives and different ways of thinking.

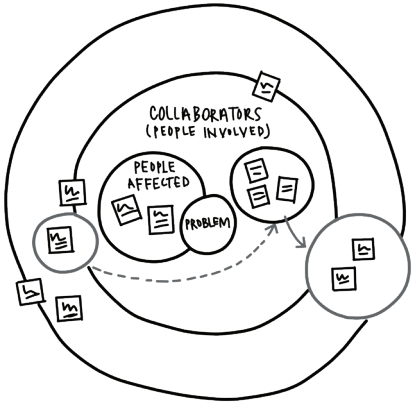
Real-World Connections: Use real-world examples that highlight the human impact of interdisciplinary work. Example: Case studies that show how interdisciplinary solutions have helped communities or individuals.

ACTIVITY IDEA: EMPATHY MAPPING

1. Introduce the concept of empathy mapping and explain its importance in interdisciplinary work.
2. Provide teachers with a central topic or problem to explore.
3. Ask teachers to create empathy maps, considering what different stakeholders representing different disciplinary and other perspectives might feel, think, say, and do regarding the topic.
4. Have teachers share and discuss their empathy maps in small groups.
5. Reflect on how empathy can enhance interdisciplinary collaboration and understanding.

WHAT IS EMPATHY MAPPING?

Empathy mapping is a tool used to understand users by visualising what they say, think, do, and feel. It helps teams create people-centred designs by identifying users' needs, pain points, and emotions.



Connecting different layers of interdisciplinary concepts through visual mapping helps teachers from different disciplines communicate more effectively, reducing misunderstandings and fostering collaboration. By visually organising ideas, teachers can better grasp complex concepts and see the relationships between different subjects. This technique is particularly useful for interdisciplinary projects, allowing maps to evolve and reflect new insights and connections as the project progresses.

MESO

PURPOSE:

To consider different levels and layers of connections between and across different disciplines.

CONSIDERATIONS FOR USE:

Developing teachers' understanding of connections between subjects can occur on many different levels. These can include:

Small connection (concept level): Integrating a brief example from another discipline when introducing a new concept. Example: Introducing fractions in math using a music rhythm exercise.

Activity in a lesson: Designing an activity that requires applying concepts from multiple subjects. Example: A science experiment that also involves measuring (math) and explaining data (English).

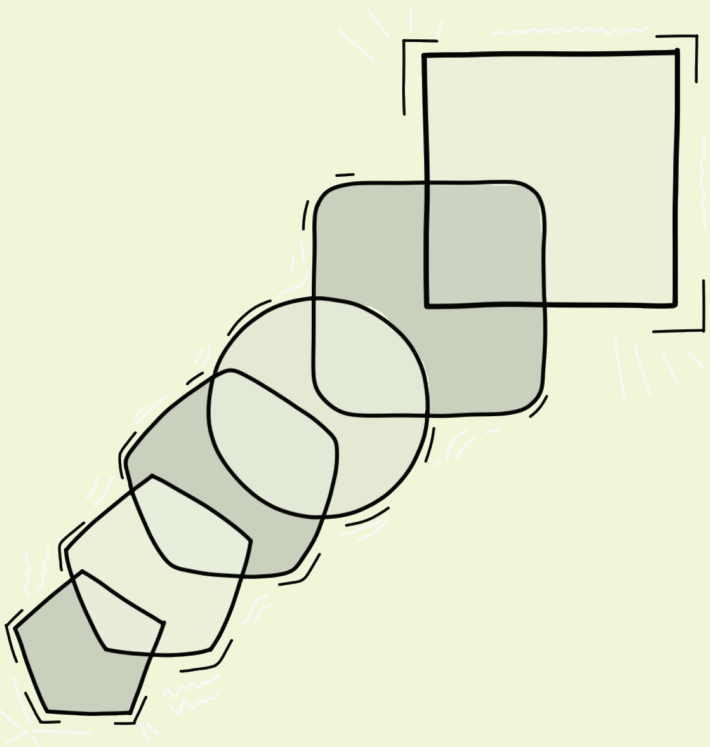
Entire lesson or series of lessons: Crafting a lesson plan or series of lessons that bridges two or more subjects. Example: A history lesson on ancient civilisations that includes visually mapping their territories (geography).

10-week unit plan: Developing a comprehensive unit that integrates multiple subjects around a central theme. Example: A 10-week project-based unit on building a sustainable city, incorporating science, math, social studies, and art.

ACTIVITY IDEA: VISUALLY MAP CONNECTION BETWEEN DISCIPLINES

1. Divide teachers into teams.
2. Provide each team with a central theme or problem at a concept, activity, lesson or unit plan level.
3. Ask teams to brainstorm and write down related concepts from their respective disciplines on sticky notes.
4. Have them arrange the sticky notes on a large poster board, drawing lines to show connections and relationships.
5. Teams present their maps, explaining how the connections enhance their understanding of the theme.

LESSON CO-PLANNING



Lesson co-planning involves collaborating with teachers from different disciplines to create integrated and cohesive lesson plans. This approach encourages sharing expertise, resources, and teaching strategies, enhancing the overall teaching and learning experience. Co-planning lessons helps teachers address complex topics more effectively and fosters a collaborative teaching culture, benefiting both teachers and students.

MESO

PURPOSE:

To collaboratively develop lesson plans that integrate multiple disciplines, enriching the learning experience.

CONSIDERATIONS FOR USE:

Collaboration Techniques: Learning strategies for effective communication and coordination among teachers are crucial for successful lesson co-design. Example: Scheduling regular planning meetings and using shared digital tools like Google Docs or Microsoft Teams.

Shared Objectives: Aligning learning objectives ensures that all subject teachers contribute meaningfully to the lesson. Example: A lesson plan sequence where mathematics, science, and technology objectives converge on a project about renewable energy.

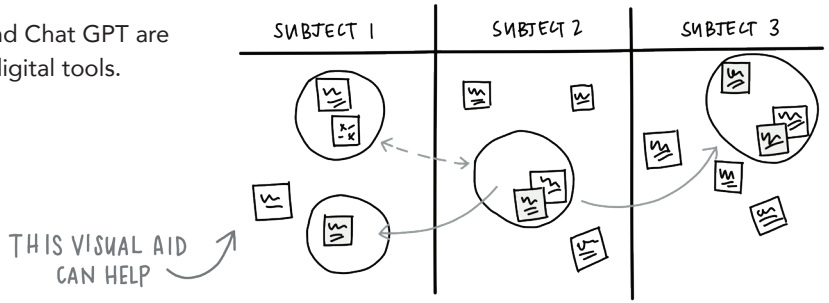
Resource Sharing: Pooling resources from different subjects can provide richer and more diverse materials for students. Example: Combining mathematics handouts, science equipment, and digital simulations for a comprehensive learning module on climate change.

Ongoing revision: Adjusting lesson plans based on student needs, feedback and classroom dynamics. Example: Modifying a lesson on the fly to better address students' questions and interests

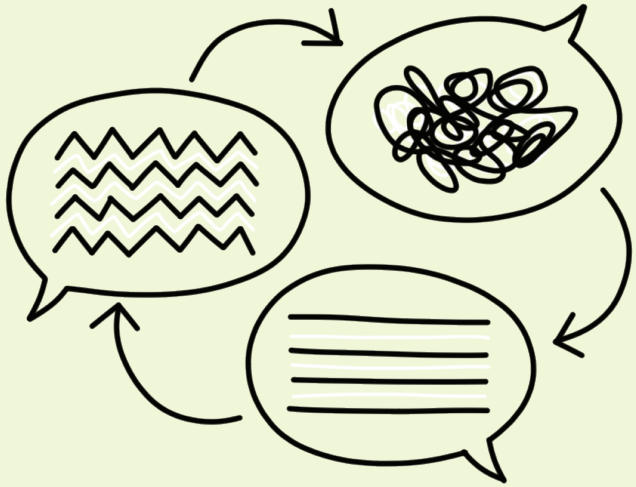
ACTIVITY IDEA: COLLABORATIVELY CREATE AN INTERDISCIPLINARY LESSON PLAN

1. Form groups of teachers from different disciplines.
2. Assign each group a central theme or problem relevant to their subjects.
3. Ask each group to brainstorm and outline the main objectives, activities, and assessments for their interdisciplinary lesson.
4. Provide templates or digital tools to facilitate the co-design process.
5. Groups present their lesson plans and receive feedback.

Note: Miro and Chat GPT are examples of digital tools.



GLOSSARY



Words can have different meanings across various subjects, which can lead to misunderstandings in interdisciplinary collaboration. Developing a shared glossary helps ensure that all teachers have a common understanding of key terms. This resource fosters clear communication, enhances collaboration, and helps teachers see the connections between different fields.

MESO

PURPOSE:

To create a shared understanding of key terms used in different disciplines.

CONSIDERATIONS FOR USE:

Identify Key Terms: Determine key terms across multiple subjects. Example: Terms like "energy," "network," and "model" can have different meanings in science, technology, and social studies.

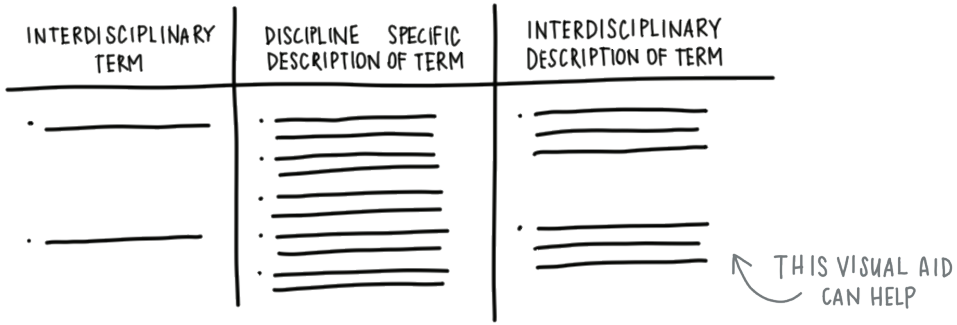
Collaboration: Involve all subject teachers in the creation of the glossary to ensure comprehensive coverage. Example: Have teachers from each discipline contribute definitions and examples.

Ongoing Updates: Keep the glossary dynamic, updating it as new terms and understandings emerge. Example: Regularly review and add new terms.

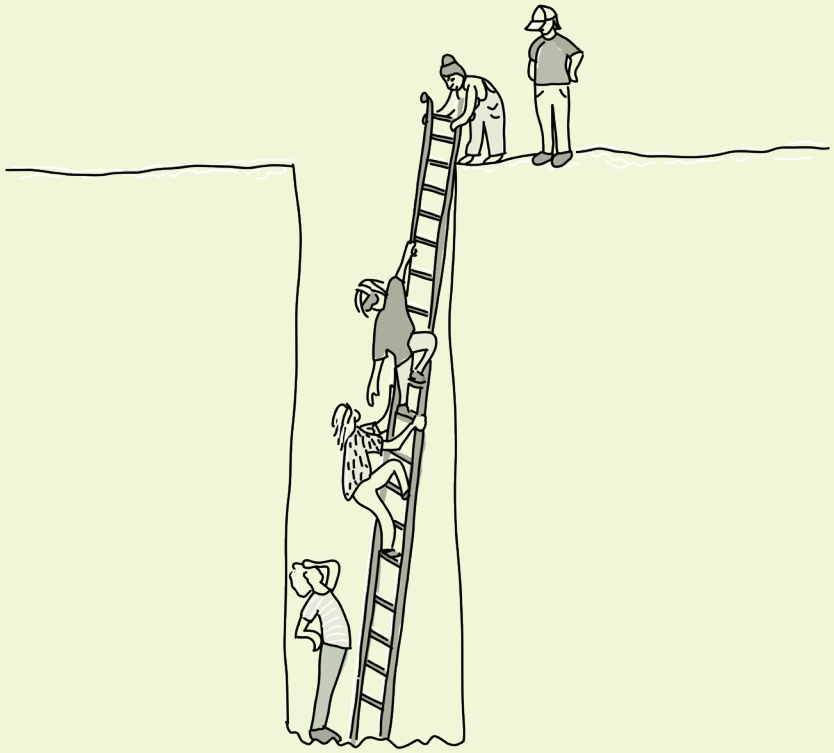
Accessible Format: Make the glossary easily accessible and easy to amend for all teachers. Example: Use digital tools like Google Docs or a classroom wiki for easy access and updates.

ACTIVITY IDEA: CREATE A GLOSSARY THAT CLARIFIES KEY TERMS

1. Form interdisciplinary groups and assign each group a set of common interdisciplinary terms to discuss and define (e.g., model, complex problem, system).
2. Each group researches and writes definitions for their terms, including examples relevant to their disciplines.
3. Compile all definitions into a single shared document.
4. Review the glossary with all teachers, discussing any terms that need further clarification.
5. Encourage teachers to refer to the glossary throughout their interdisciplinary lesson planning and update it as needed.



MENTORS



Mentoring in the context of interdisciplinary teaching involves experienced teachers guiding less experienced teachers in integrating multiple disciplines into their teaching. This support helps mentees develop new skills, gain confidence, and foster creative teaching practices. Effective mentoring promotes a culture of continuous learning and collaboration among teachers, building interdisciplinary expertise.

MESO

PURPOSE:

To provide guidance and support for teachers in integrating interdisciplinary approaches into their teaching practices.

CONSIDERATIONS FOR USE:

Mentor-Mentee Relationship: Establish a clear, supportive, and respectful relationship between mentors and mentees. Example: Regular check-ins and open communication channels.

Goal Setting: Set clear and achievable goals for the mentee's professional development. Example: Developing a plan to integrate interdisciplinary projects into the curriculum over a semester.

Resource Sharing: Mentors provide access to materials, strategies, and networks that can aid the mentee's growth. Example: Sharing lesson plans, teaching tools, and professional development opportunities.

Feedback and Reflection: Continuous feedback and reflective practices to help mentees improve and innovate. Example: Conducting post-lesson reflections to discuss what worked well and what could be improved.

ACTIVITY IDEA: MENTORING SESSION

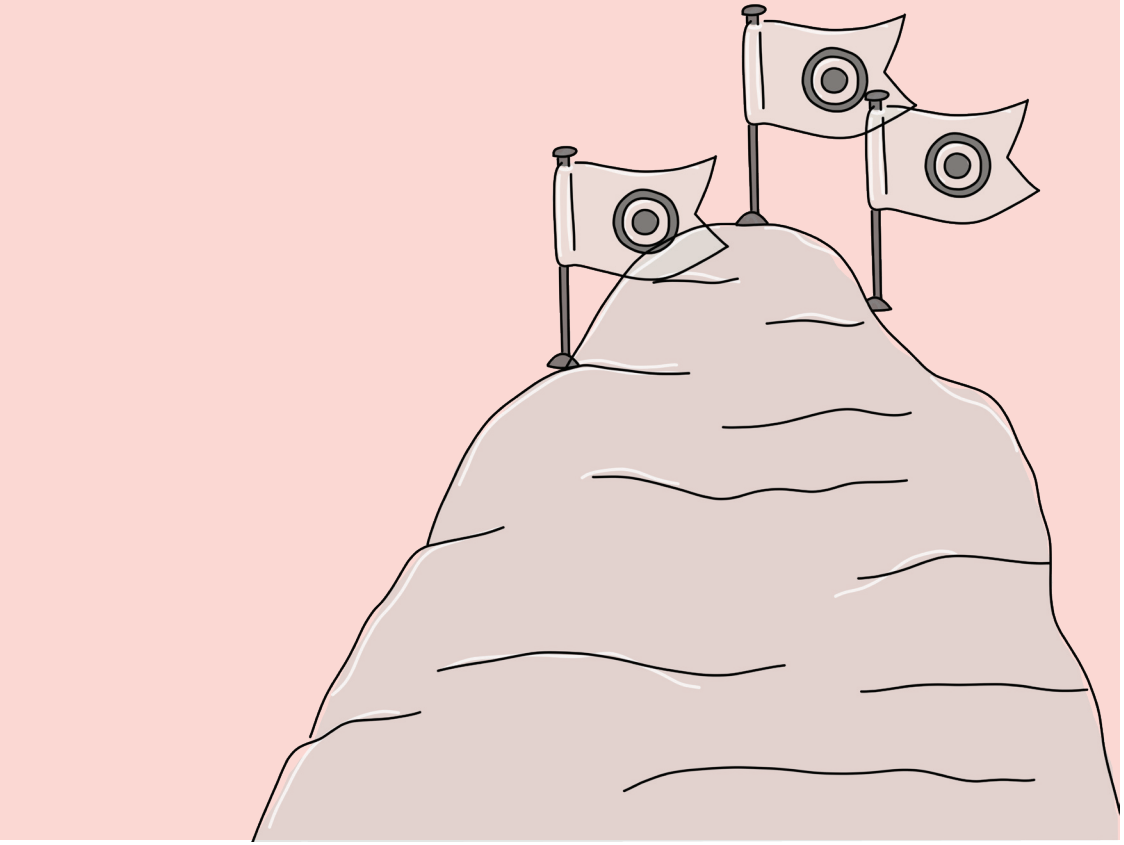
1. Pair mentors with mentees based on their disciplines and interests.
2. Conduct an initial meeting to set goals and discuss the mentee's needs.
3. Mentors share resources and strategies relevant to interdisciplinary teaching.
4. Mentees design an interdisciplinary lesson plan with the mentors' guidance.
5. After the lesson, mentors and mentees reflect on the experience, discussing successes and areas for improvement.

THIS VISUAL AID CAN HELP

SMART GOALS

S	SPECIFIC
M	MEASURABLE
A	ACHIEVABLE
R	REALISTIC
T	TIMED

LEADERSHIP



Effective leadership is essential for fostering an interdisciplinary culture within school systems and communities. Interdisciplinary leaders should have capabilities to co-create the vision, provide support, and create an environment where interdisciplinary teaching and learning can thrive. They play a crucial role in aligning resources, policies, and practices to support interdisciplinary teaching and learning. It is important to develop interdisciplinary leardership capabilities of individual teachers and schools.

MACRO

PURPOSE:

To cultivate leadership that champions and supports interdisciplinary initiatives.

CONSIDERATIONS FOR USE:

Vision and Goals: Leaders should learn strategies for articulating a clear vision and set goals for interdisciplinary education. Example: Developing a school-wide initiative to integrate STEM and humanities subjects.

Support and Resources: Leaders should know strategies for planning and providing necessary resources and professional development. Example: Identifying needs and offering workshops and materials on interdisciplinary teaching strategies.

Encouragement and Recognition: Recognise and reward efforts and successes in interdisciplinary teaching. Example: Implementing a recognition program for innovative interdisciplinary projects.

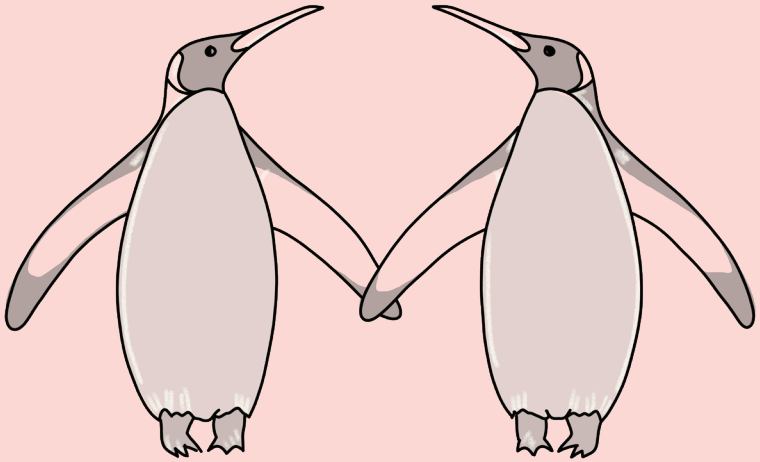
Policy and Structure: Create policies and structures that facilitate interdisciplinary learning. Example: Adjusting schedules to allow for collaborative planning time among teachers.

Collective Leadership: Focus on leadership culture, capabilities and establishing processes that recognise and value different kinds of leadership in interdisciplinary teaching.

ACTIVITY IDEA: DEVELOP A VISION FOR INTERDISCIPLINARY EDUCATION

1. Organise a workshop for school leaders and teachers.
2. Guide school teachers in creating a vision statement and setting actionable goals.
3. Collectively develop a plan for development of interdisciplinary teaching
4. Follow up with regular check-ins and support to ensure progress.

COLLABORATIVE CULTURE



Valuing collaboration involves recognising and promoting the importance of working together across disciplines. It requires building a culture where collaborative efforts are encouraged, supported, and celebrated. This culture enhances the educational experience by bringing diverse perspectives and expertise to the learning process.

MACRO

PURPOSE:

To foster a culture that recognises and promotes interdisciplinary collaboration.

CONSIDERATIONS FOR USE:

Incentives and Recognition: Create systems to recognise collaborative efforts. Example: Offering incentives for teachers who regularly collaborate on interdisciplinary projects.

Professional Development: Provide training and support for effective collaboration. Example: Holding workshops on collaborative teaching methods.

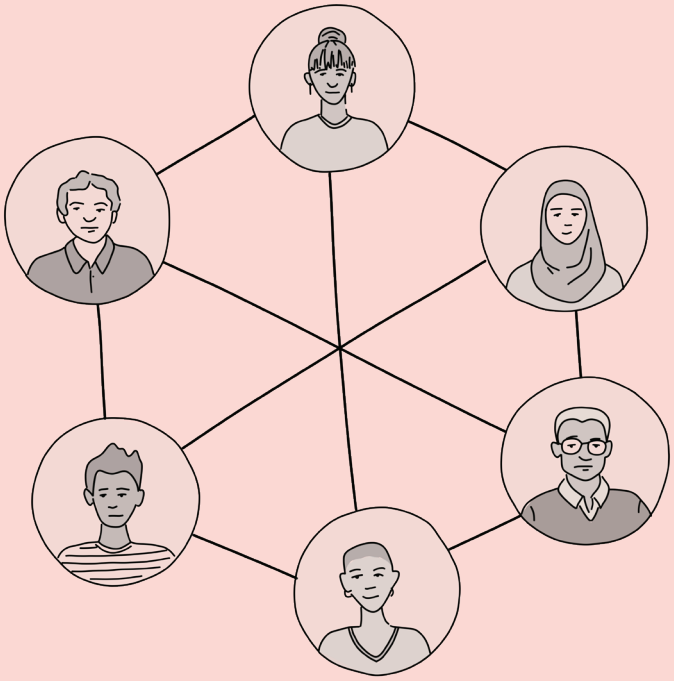
Celebrating Successes: Highlight and celebrate successful collaborations. Example: Showcasing interdisciplinary projects at school events.

Collaborative Spaces: Designate physical or virtual spaces for collaboration. Example: Setting up a collaborative workspace or online forum for teachers.

ACTIVITY IDEA: COLLABORATIVE CULTURE BUILDING

1. Conduct an anonymous online survey to assess current attitudes towards interdisciplinary collaboration.
2. Hold focus groups to identify barriers and opportunities for interdisciplinary collaboration.
3. Develop a plan to address identified barriers and enhance interdisciplinary collaborative practices.
4. Implement initiatives such as collaboration awards, professional development sessions, and dedicated collaborative spaces.
5. Regularly evaluate and adjust the plan based on feedback and outcomes.

COMMUNITIES OF PRACTICE



Communities of practice are groups of teachers who come together to share knowledge, practices, and experiences. These communities foster continuous learning and improvement, enabling teachers to develop and refine interdisciplinary teaching practices. By participating in communities of practice, teachers can collaborate, innovate, and support each other in their professional growth.

MACRO

PURPOSE:

To build and sustain communities where teachers can share and develop interdisciplinary teaching practices.

CONSIDERATIONS FOR USE:

Regular Meetings: Schedule consistent and structured meetings for communities of practice. Example: Monthly meetings with specific agendas and goals.

Shared Resources: Create an online repository for sharing lesson plans, materials, and research. Example: Using an online platform like Google Drive or a dedicated website.

Peer Support: Encourage peer mentoring and collaborative problem-solving. Example: Pairing experienced teachers with newcomers for mentorship.

Reflective Practice: Incorporate reflection and feedback into community activities. Example: Reflective discussions and feedback sessions at the end of each meeting.

ACTIVITY IDEA: ESTABLISH A COMMUNITY OF PRACTICE

1. Identify interested teachers and form a core group.
2. Hold a kick-off meeting to discuss the purpose, goals, and structure of the community.
3. Establish regular meeting times and communication channels.
4. Develop a shared vision and plan for the community's activities.
5. Start with an initial project or topic to build momentum and engagement.
6. Identify emerging leaders and empower them to shape community activities.

Note: This activity can also extend beyond your physical school community. Use digital tools go reach and connect across multiple school communities.

INSTITUTIONAL SUPPORT

Institutional support involves aligning school policies, resources, and administrative practices to support interdisciplinary teaching and learning. This support ensures that interdisciplinary initiatives are sustainable and integrated into the school's broader educational goals. Institutional backing provides the necessary foundation for successful interdisciplinary collaboration..

MACRO

PURPOSE:

To provide the structural and administrative support needed for interdisciplinary initiatives to thrive.

CONSIDERATIONS FOR USE:

Policy Alignment: Ensure school policies support interdisciplinary professional learning and teaching. Example: Policies that allow flexible scheduling for interdisciplinary projects and embeds teachers' interdisciplinary learning into new projects.

Resource Allocation: Allocate resources such as funding, materials, and time for interdisciplinary infrastructure. Example: Budgeting for interdisciplinary project supplies and professional development creating maker-spaces.

Administrative Support: Engage school administrators in learning to support and promote interdisciplinary initiatives. Example: Administrators attending and participating in interdisciplinary planning meetings.

Sustainability: Develop long-term plans to sustain interdisciplinary programs. Example: Establishing a dedicated interdisciplinary coordinator role.

ACTIVITY IDEA: ALIGN POLICIES AND RESOURCES

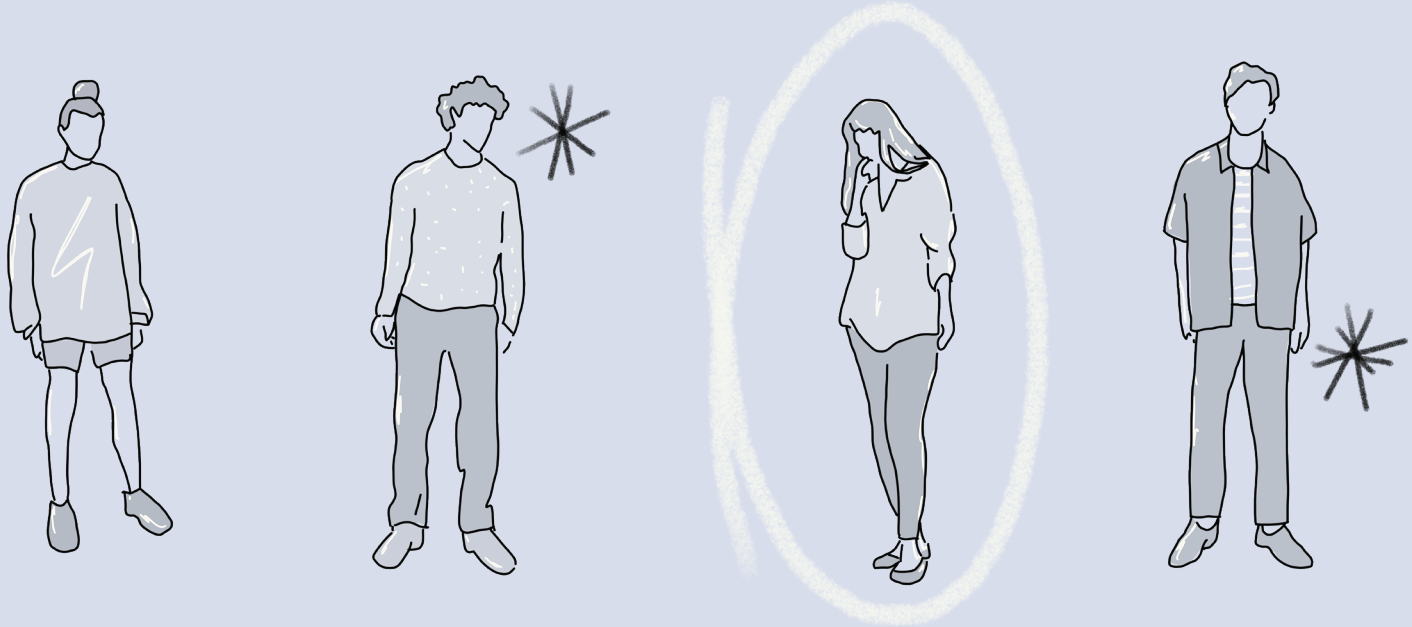
1. Hold a meeting with school leaders, teachers and key stakeholders.
2. Review current policies and resources related to interdisciplinary teaching. Identify gaps and areas for improvement.
3. Develop a strategic plan to enhance institutional support for interdisciplinary initiatives.
4. Implement the plan and establish regular review sessions to ensure ongoing alignment and support.

SUMMARY

The sketched design principles for teachers' interdisciplinary learning in this section span **micro**, **meso** and **macro** levels and simultaneously relate to **epistemic** (knowledge, skills, etc.), **material** (resources, structures, etc.), **social** (relations, language, etc.) and **affective** (emotions, values, solidarity, etc.) aspects of interdisciplinary practices.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

CASE STUDIES



EXAMPLES OF INTERDISCIPLINARY EXPERTISE DEVELOPMENT RESOURCES

OVERVIEW OF CASE STUDIES

This final section presents five examples of interdisciplinary expertise development resources. Each case study follows a similar structure and layout, breaking down an example of interdisciplinary teaching and learning in practice.

The five case studies are:

1. **Enhancing Pedagogy for Integrating Science and Language** by Louise Sutherland
2. **"GenAI" in Intial Teacher Education - Enhancing Student Teachers Interdisciplinary Expertise and Agency** by Hongzhi Yang
3. **Uniting a Variety of KLA Outcomes to Reach a Shared Learning Goal** by Nicola Currie
4. **Exploring Wind Turbines** by Martin Levins
5. **Learning by Design for Playful Learning of Interdisciplinary Topics** by Peter Reimann

Building on the main facets of teachers' interdisciplinary practices explored on pages 9-11, the five case studies in the following section can be mapped to each facet, as illustrated on the following page.

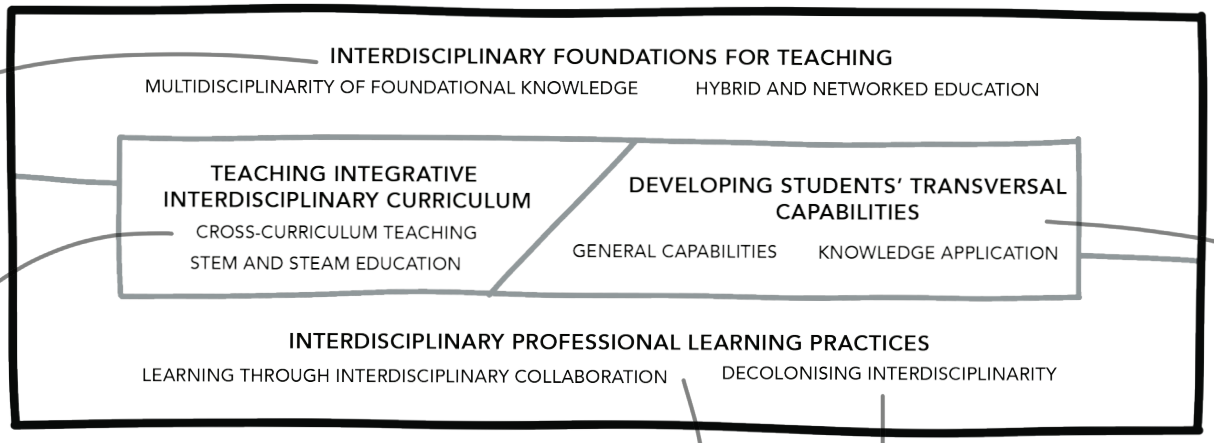
GENERAL TEMPLATE OF EACH CASE STUDY

- **Context and Application Background**
  Overview of the background and relevance for interdisciplinary teachers' professional learning
- **Key Concepts**
  Definition of key terms and concepts for both teacher educators and pre-service and in-service teachers relevant to the background and application area
- **Capabilities**
  Specific capabilities and skills pre-service and/or in-service teachers will develop
- **Aims and Purpose**
  The goals of the case and objectives of the resource
- **Approach**
  Approach or framework guiding the development of teachers' interdisciplinary expertise
- **Activities**
  Description of the activities for professional learning
- **Tools and Resources Required**
  List of materials and tools required (including digital tools, reference list, online resources)
- **Assessment Guidelines**
  Outline of outcomes of professional learning will be evaluated or how student teachers will be assessed
- **Reflections and Lessons Learnt**
  Insights gained through the development and implementation of the case study

PLEASE NOTE:

Each of the five case studies are different. They each follow the above general template but they all vary in specifics.

MAIN FACETS OF TEACHERS' INTERDISCIPLINARY PRACTICES



CASE STUDY 1

ENHANCING PEDAGOGY FOR INTEGRATING SCIENCE AND LANGUAGE

- STEM AND STEAM EDUCATION
- CROSS-CURRICULUM TEACHING

CASE STUDY 2

"GEN AI" IN INITIAL TEACHER EDUCATION

- HYBRID AND NETWORKED EDUCATION

CASE STUDY 3

UNITING A VARIETY OF KLA OUTCOMES TO REACH A SHARED LEARNING GOAL

- LEARNING THROUGH INTERDISCIPLINARY COLLABORATION
- KNOWLEDGE APPLICATION

CASE STUDY 4

EXPLORING WIND TURBINES

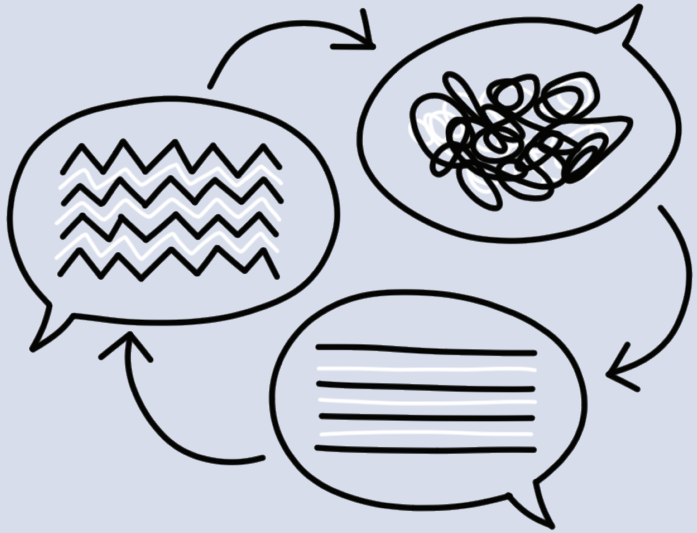
- GENERAL CAPABILITIES
- KNOWLEDGE APPLICATION

CASE STUDY 5

LEARNING BY DESIGN FOR PLAYFUL LEARNING OF INTERDISCIPLINARY TOPICS

- MULTIDISCIPLINARY OF FOUNDATIONAL KNOWLEDGE
- DECOLONISING INTERDISCIPLINARITY

ENHANCING PEDAGOGY FOR INTEGRATING SCIENCE AND LANGUAGE



IN-SERVICE TEACHERS' PROFESSIONAL INTERDISCIPLINARY LEARNING

LOUISE SUTHERLAND
THE UNIVERSITY OF SYDNEY

This case is based on the project Funded by the NSW Department of Education Equity Unit and Centre for Educational Statistics and Evaluation.

CONTEXT

Like many other English-speaking countries, Australia has seen marked increases in the population of students learning English as an Additional Language or Dialect (EAL/D) (ACARA, 2024). These students need English to succeed in school study, but the research indicates that it takes five to seven years on average for these students to develop the formal academic language (Cummins, 2021). In NSW, students from EAL/D backgrounds move from intensive language centres into local high schools after 12 months.

Discipline-specific academic language is an important part of disciplinary literacies (Goldman et al., 2016) and interdisciplinary learning (Schwarz et al.,2024). These students need additional language support to develop the formal language they need for each school subject (Ardasheva et al., 2016). Their subject teachers are unlikely to have the knowledge and skills to provide the nuanced EAL/D students support they need (Buxton et al., 2013). English as a Second Language (ESL) teachers support EAL/D students in developing their formal language, but this is often provided through a withdrawal program or ad hoc support in the classroom.

A partnership between ESL and subject teachers provides an opportunity to enhance the professional learning of both teachers when they work on a common purpose aiming to integrate ESL learning in the mainstream classrooms, while simultaneously scaffolding EAL/D and native English speakers who need additional language support.

This was the purpose of this collaborative school-based professional development initiative designed for teams of ESL and Science teachers. It focused on the integration of language learning and Science using a collaborative curriculum design approach (Voogt et al., 2015). At its core was a school-based teachers' collaborative Science lesson planning and implementation drawing on the Rich Task pedagogy, which engages students in learning Science through inquiry activities focused on the application of Science in everyday life (Aubusson et al., 2014; Moulds, 2002). This model of professional learning supports disciplinary integration and can be extended to other school subjects (e.g., history, mathematics, and geography) and cross-curriculum topics (e.g., STEM, STEAM, and sustainability). It was developed by university partners and trialled in the context of Science to support EAL/D students' learning of formal science language while simultaneously scaffolding a broad range of linguistic skills important in everyday contexts.in Year 8 in eight NSW schools from lower SES areas.

AIMS AND PURPOSE

The overarching aim of this professional development initiative is to enhance ESL and subject teachers' capabilities to teach English as an additional language in the context of their subjects or integrated curriculum.

The main purposes are:

1) To implement a collaborative school-based professional learning model for enhancing integrated ESL teaching and learning across subjects
2) To enhance teachers' interdisciplinary collaboration by engaging them in curriculum co-design and implementation
3) To enhance the knowledge and skills of ESL and subject teachers in supporting EAL/D students' language development in mainstream classrooms
4) To enhance teachers' capabilities to use integrative, inclusive to language learners, pedagogies (e.g., Rich Tasks)

CAPABILITIES

Teachers enhance the following main capabilities:

1) To integrate language teaching and learning across subjects, focusing on scaffolding EAL/D students' development of formal subject-specific language
2) To co-design and co-teach lessons that integrate language and disciplinary learning through inquiry activities focused on applying subject knowledge and disciplinary language in everyday life

APPROACH

This professional learning model is underpinned by a complex systems perspective (Sutherland et al., 2023). Teachers exert their agency in decision-making and complex problem-solving when collaborating to develop and implement lessons to enhance students' learning experiences (Tronsmo, 2019). These processes are complex; an in-depth understanding of the subject matter (i.e., content knowledge) and knowledge of how students learn it (i.e., pedagogical content knowledge) from multiple curriculum areas (e.g., ESL and Science) is essential. Teachers also need understanding and skills to integrate and enact knowledge from multiple subject domains when teaching within the wider school context. This requires capabilities to engage in diverse *epistemic practices*, such as the use of inquiry in teaching and integrated curriculum co-design, as well as capabilities to engage in diverse situated *relational practices*, such as coordination, collaboration, management of teamwork and school resources, sensitivity to students' backgrounds and care (Figure 1).

Therefore, teachers' professional learning outcomes are multicausal and multidimensional. ESL and subject teachers must actively participate in their learning, refining their knowledge and adjusting teaching approaches to meet the specific needs of their students, classrooms, and schools (Reid & Kleinhenze, 2015). Their learning is the simultaneous transformation of themselves, the students, the knowledge produced, and the school practices. This transformation arises from synergistic interactions between the different entities or groups of entities, such as teachers or students within the wider school context (Levy & Wilensky, 2008). From a complex systems perspective, while the school provides the Macro context, interactions among the teachers in their teams and other people at the Meso level create feedback loops that, with time, contribute to the outcomes of an interdisciplinary professional development initiative (Daly et al., 2020; Shaked & Schechter, 2016, 2019). This includes changes in the capabilities of individual teachers that occur at the Micro level (Figure 1).

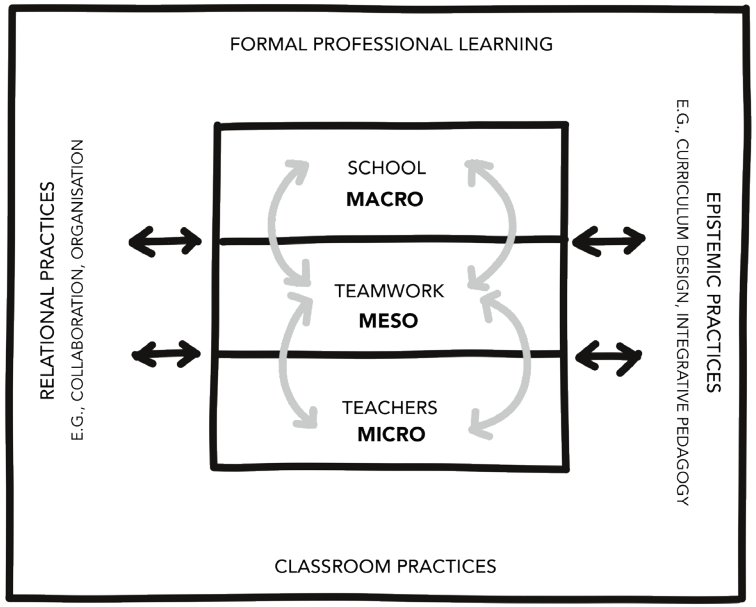


Figure 1: The professional learning model

In designing this professional development initiative, we adopted two principles. First, we used a *school-based approach* to help teachers align professional learning with the needs and opportunities of their schools. Secondly, we used collaborative curriculum co-design to structure and direct the teachers' collaboration and professional learning activities. Curriculum co-design and implementation, therefore, served as a vehicle for in-service teachers' interdisciplinary teamwork and professional learning.

In addition to the *collaborative curriculum design*, this professional development initiative was based on two specific principles for integrating Science and language learning: 1) contextualising Science learning through the development of a 'Rich Task' (Aubusson et al., 2014; Moulds, 2002); and 2) purposefully embedding language in Science instruction.

KEY CONCEPTS

RICH TASKS

Recent developments in Science education for EAL students suggest that Science instruction should be organised around a meaningful context, problem, or questions to frame their learning (Lee et al., 2019). Within this meaningful context, students should be supported in understanding Science concepts, explaining phenomena, and solving problems. One way is to base the curriculum design on the concept of a Rich Task (Moulds, 2002; Sutherland, 2021). Rich tasks are grounded in questions that students encounter in their lives and usually result in a substantial intellectual product that students produce through engagement in inquiry. They are intellectually challenging, engaging and motivating for students as they relate to students' interests and involve them in working with other students. The main characteristics of Rich Tasks are summarised in Figure 2.

Rich Tasks:

1. Serve as culminating performances with clear purposes.
2. Focus on students, requiring active engagement in the learning process.
3. Involve students in acquiring, refining, extending, and applying their knowledge.
4. Offer sufficient intellectual, cognitive, and developmental depth and breadth to support differentiation in classroom learning.
5. Are problem-based.
6. Draw on practices and skills from one or more disciplines, ensuring the integrity of each discipline is maintained when multiple are used.
7. Connect to the world beyond the classroom.
8. Develop key concepts and ideas from one or more disciplines.
9. Allow students to demonstrate reflective, creative, and critical thinking characteristics.
10. Enhance students' complex reasoning processes, including higher-order thinking skills such as problem-solving, decision-making, and evaluation.

Figure 2: Main characteristics of Rich Tasks

Rich Task pedagogy involves five inquiry stages (5E): Engage, Explore, Explain, Elaborate and Evaluate. These stages engage students in diverse language practices, creating rich opportunities for integrating language learning into inquiry activities (Table 1). The focus on Rich Tasks helps teachers learn to: 1) design a curriculum around inquiry challenges that are meaningful for students, 2) design for and scaffold students' learning to participate in different inquiry practices and 3) embed the development of language into diverse inquiry practices.

Rich task (5E)	Inquiry practices	Language practices
Engage	Learning to 'see' and understand 'science' in everyday life	Developing students' language for understanding 'lay' science (news, etc.)
Explore	Learning to design and conduct the inquiry	Developing students' language to contribute to science inquiry (understand key concepts, design experiments, record findings, discuss with peers, etc.)
Explain	Learning to understand and explain formal scientific ideas	Developing students' language to interact in formal scientific discourse/genres
Elaborate (express and enact)	Learning to connect science to everyday life, and convey ideas in diverse formats for different audiences	Developing students' language to use different genres for different audiences
Evaluate	Learning to self-evaluate inquiry processes, outcomes, implications, etc.	Developing language to talk about and evaluate science practices, outcomes, etc.
Teachers learn to design curriculum around inquiry challenges that are meaningful for students	**Teachers learn how to design for and scaffold students' learning to participate in different inquiry practices**	**Teachers learn to embed the development of language into diverse inquiry practices**

Table 1: Links between Science and language practices in the main stages of Rich Tasks

DESIGN AND IMPLEMENTATION [1]

The professional development initiative was co-designed and led by university partners consisting of ESL, Science and Professional Learning experts, who also acted as mentors for school teams.

Most of the professional learning was school-based. Each participating school was asked to form a small interdisciplinary team consisting of Science and ESL teachers and a Science headteacher. The teachers created a small professional learning community focusing on the collaborative curriculum design of a section of the Year 8 Science program.

The initiative was conducted over approximately 15 weeks. It consisted of four formal professional development days, three informal school-based meetings with the teachers at the school and their university mentors and a set of meetings of the teachers involved in the project.

Using the Rich Task and embedded language support principles, each team redesigned a Science unit in the Stage 4 program (Years 7–8) to support EAL students' language development while learning Science.

Each team was given twenty hours of teacher relief to support the curriculum redesign. In addition to the co-planning of the lessons, the expectation was that the ESL and Science teachers would co-teach the class.

The design of the professional development initiative included four phases: 1) Expression of interests; 2) Professional learning days at the beginning of the project; 3) School-based design and implementation of Rich Tasks; and 4) Follow-up professional learning.

[1] This section is based on Sutherland (2021).

PHASE 1: EXPRESSION OF INTEREST

Given the demands of the collaborative curriculum design, we considered the personal teachers' resources (i.e., knowledge, interests) as well as school resources the participants would need for this professional learning project. Schools were required to submit an Expression of Interest (EOI) detailing the relationship of this professional learning project to their school planning goals (Macro), and each teacher had to identify their goal for the project (Micro) (Figure 1). In the EOI, each school was asked to nominate a team of teachers (Meso) consisting of 1) the Head Teacher of Science, who was to provide the leadership in the development and implementation, 2) a Science teacher who would be working with a class of EAL/D students; and 3) a specialist ESL teacher (Figure 3).

Position	Teaching experience	What I hope to gain from this project in terms of my professional learning and outcomes for my students
Project leader Name: Completed TELL: Yes/No		
EAL/D Specialist Name: Completed TELL: Yes/No		
Year 8 Science teacher Name: Completed TELL: Yes/No		
Team member (optional) Name: Completed TELL: Yes/No		

Brief description of the proposed project: How can focusing on EAL/D student data improve Science outcomes for English language learners in Year 8 Science?

Figure 3: Template for the expression of interest

NOTE: TELL – means a professional learning course "Teaching English Language Learners"

PHASE 2: PROFESSIONAL LEARNING DAYS AT THE BEGINNING OF THE PROJECT

The scope and purpose of the initiative were discussed in two professional learning days at the beginning of the project. In these two sessions, the concepts of a Rich Task, scaffolding language development by moving from oral to written language methods, and identifying students' initial level of language development from their oral and written responses were discussed.

First, the differences between everyday and scientific language were discussed, and the teachers were provided with examples of how to identify the development of students' scientific language and their understanding of scientific concepts. For example, teachers were shown transcripts of students' recall of a Science lesson and supported to identify the use of formal Science language and terminology (Figure 4).

Daniella

T: Can you tell me what you did today, and can you list as many steps as you can remember?

Ah, we .. ah.. tried to measure .. Like .. differences in heat with different ..ah.. type .. with different types of houses and used a.. a house with long glass, another house with insulation and another house with double glaze. And ..ah .. used a heater thing that connected to this thing to give it light that acted as the sun. and we recorded it with a data logger and then we waited for .. like .. to see the difference in temperature

Scaffolded answer – visual support – previously given question - Uptake of Science noun and verb groups – formal language

Figure 4. Transcript of EALD's students' recall of the previous lesson

NOTE: The highlighted words show the student's use of Science concepts and formal science language.

Second, the relationship between the syllabus organisation and a Rich Task was discussed. In developing their Rich Task, teachers were asked to select an appropriate aspect of the school Science program, identify the key concepts and disciplinary processes, and then, using backward mapping, develop a sequence of lessons to support students' formal language development (Figure 5).

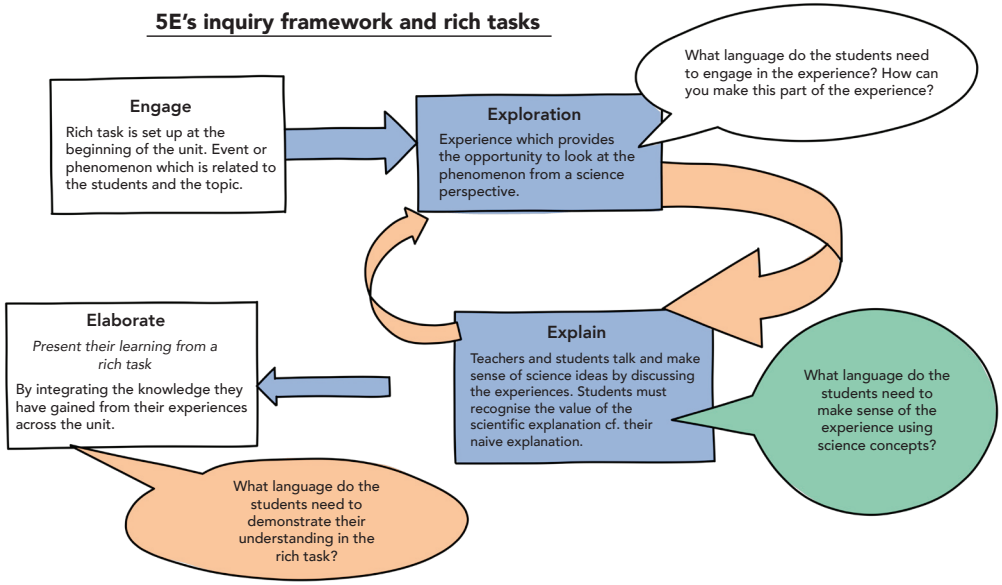


Figure 5. A scaffold to assist teachers in identifying language requirements in Rich Tasks

To assist with this task, an example of a Rich Task was used to show a storyline asking teachers to identify language requirements that students would need to understand the relevant Science concepts and processes (Table 2).

Rich Task: Energy drinks

Syllabus outcomes:

LW3: Multicellular organisms contain systems of organs that carry out specialised functions that enable them to survive and reproduce
LW4: Scientific knowledge changes as new evidence becomes available, and some scientific discoveries have significantly changed people's understanding of the world

Phase	Activity	Storyline	Task descriptions	Language requirements
Engage	Introduction to the task	Students are to become doctors who are leaders for their community, promoting healthy products and services.	Introduce role play and the types of roles and responsibilities students will take on for these lessons.	
	Model of product	Example of what they would produce.	E.g., a letter to producers of V or Redbull about advertising these products to children, citing evidence of the impact of caffeine on health.	
		What do they already know about systems in the body? What do they want to find out?	Create an outline of the human body as a model identifying the systems within the body and the organs associated with each system. Provide examples of common symptoms/ diseases linked to multiple body systems. Students identify the links to different body systems.	
Explore & Explain	Modelling the problem -> solution	Why does Jamie Oliver want Redbull banned for kids?	What is in Redbull or V? Analysis of package labels Compare to other drinks. A video resource What impact does caffeine have on people's heart rate? Students measure teachers' heart rate before and after 15 min after they have had a cup of coffee, coke or chocolate. Look at patterns in graphs from 2nd hand data - the impact of caffeine heart rate. Telling the story from the graph.	
		How does the caffeine get from the drink to my heart?	What happens in the digestive system? Role of the circulatory system and nervous system	
Elaborate & Evaluate	Working on the final product	Writing a persuasive, supported by evidence letter or producing another artefact.	E.g., Letter/ email to producers of V or Redbull about advertising these products to children explaining the impact of caffeinated drinks. Feedback and discussion	

Table 2: Example of a storyline for Rich Task

PHASE 3: SCHOOL-BASED DESIGN AND IMPLEMENTATION OF RICH TASKS

The school-based focus was key to the project, with school teams and university partners meeting 2-3 times at each school. University academics who acted as mentors assisted teachers in the initial stages of the project by engaging in school-based conversations. In the first meeting at each school, the focus of the discussion between the university mentors and the participating teachers was the development of a meaningful context for a Rich Task. Before the meeting, the teachers had identified a relevant Science unit from their existing programs and were aware of their students' language issues. Students' prior experiences and the Science concepts in the unit provided the basis for brainstorming a possible context.

In the subsequent meeting, the focus of the discussion was the rich task. A team of teachers needed to identify an appropriate topic or unit in their program as well as the nature of what the students should produce. Once the school teams identified a concrete product the students might produce, they used backward mapping to identify the language demands of the final task and create a sequence of lessons to scaffold students' learning. Examples of Rich Task topics and assessments/products chosen by schools are shown in Table 3.

An example of a Rich Task developed by one teachers' team is shown in Figure 6. The two main components, the speaking and writing tasks, require the students to conduct an inquiry and use their findings in communicating with two different audiences.

Topics for Rich Tasks	Assessment/product
Why is the mobile phone overheating?	An oral and written report
Body systems: Organ transplants	Roleplay and letter describing why an organ transplant is a need
Tides: Fishing	Brochure as a piece of persuasive text
Home insulation	Model and oral report
Filtration – the river story	Storyboard
Features of the solar system	Brochure advertising a planet
Energy transformation	Rube-Goldberg model and oral presentation

Table 3: Examples of topics for Rich Tasks and assessments

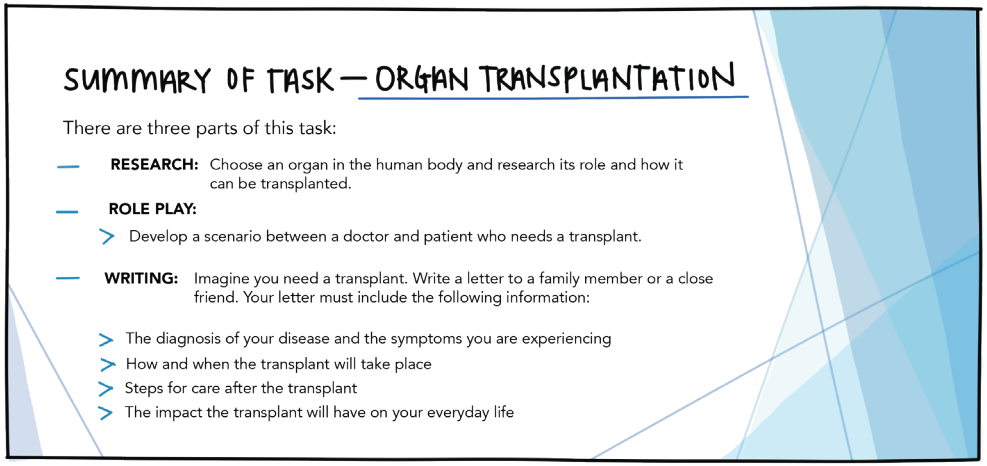


Figure 6. An example of a Rich Task

Most of the decision-making was made in the school-based meeting amongst the teachers (Meso level). At the Macro level, schools allocated planning time for the teachers and organised the timetable so that the Science and ESL teachers team co-taught the targeted class. This co-teaching was critical, allowing for refining teaching and learning interdisciplinary practices.

PHASE 4: FOLLOW-UP PROFESSIONAL LEARNING

Approximately eight weeks later, the teachers reassembled for the third professional learning day. In this session, teachers shared their progress in informal discussion groups.

Between the third and fourth professional learning days, the academic mentors conducted follow-up school visits to about half of the schools to discuss the progress. They helped the teams reflect and identify the key outcomes they would present to other schools on the final professional learning day. In the fourth and final session, each school team made presentations to their peers.

Finally, approximately ten months later, teachers were invited to participate in a series of webinars where they shared the insights of the initiative with teachers from other schools.

TOOLS AND RESOURCES REQUIRED

Follow-up readings

Sutherland, L. (2021). Science and Language: Lessons from a curriculum co-design. *Teaching Science*, *67*(4), 41-52.

Sutherland, L., Markauskaite, L., & Cruickshank, K. (2023). A complex systems framework for examining the impact of school-based professional learning initiatives: emerging agentic practices in a collaborative curriculum redesign. *Professional Development in Education*, *49*(6), 1087-1102.

Related resources

Integrating Rich Tasks
https://nrich.maths.org/6089

English as an additional language or dialect
https://education.nsw.gov.au/teaching-and-learning/multicultural-education/english-as-an-additional-language-or-dialect

REFLECTIONS AND LESSONS LEARNT

Unlike traditional professional development courses, this this school-based professional learning program included limited formal teachers' instruction. The professional learning sessions were designed to highlight the issues and approaches the teams should consider when integrating language learning in Science (e.g., Rich Tasks, formal scientific language). Therefore, professional learning and curriculum co-design drew significantly upon the expertise that teachers and schools already had. Teachers' agentic decision-making at the Meso level was critical for achieving the project's outcomes (Figure 1). The Macro and Micro levels directly and indirectly impact these decisions.

MACRO LEVEL

At the Macro level, the resources and culture within the school were the key factors. Time for joint planning, co-teaching, and reflection was the most critical resource. The professional development initiative provided funding for teaching relief for five days for each participating teacher; all teachers identified this relief as critical for success. Further, the school's support of changes in school programs and assessments was also critical. The possibility of modifying existing programs enabled teachers to increase the relevance of the Rich Tasks, learning activities and assessments. For example, at one school, this included adding an excursion in response to students' challenges and understanding the links between their learning and real-world experiences (i.e., tides and fishing); at another school, this included changes in the planned lessons in response to identified additional students' learning needs (e.g., learning to draw graphs). Leadership was critical as the projects were implemented over two school terms and teaching teams needed to coordinate their actions and directions. At least one member of the team needed to take a leadership role to drive and sustain the project.

MESO LEVEL

The enactment of changes in pedagogical practices was essential for the success of a professional development initiative. In the initial stages, the Science teachers identified the topic area. In the meetings with the academic mentors, the possible directions for a Rich Task were brainstormed. This is where the flexibility of the team members—and school culture, which supported change in the school program and approach—was important. If the teachers or the school were not prepared to reconsider or reorganise their program, this impacted the possibilities to create authentic Rich Tasks and achieve broad-ranging positive outcomes.

The interactions at the Meso level determined the overall success of the project. Following the team's decision on the direction of the project, the Science skills and conceptual understanding were identified by the Science teachers. The ESL teachers' knowledge and skills were important in deciding how these relevant concepts would be introduced and how the development of the language skills would be scaffolded. The teachers' expertise in collaborating, co-designing, and implementing the curriculum was critical, as the initiative was school based. More targeted professional learning and support of implementation processes may have enhanced the outcomes at some schools where this expertise was still developing.

Overall, the team needed skills to engage in diverse collaborative curriculum-making practices as the team members' roles and responsibilities ranged from the initial planning to the implementation and refinement of the strategies.

MICRO LEVEL

At the micro level, the attributes of more successful teams and teachers included:

• *The motivation of the individual participants.* Teachers reported that planning, implementing, and reflecting on the changes in the practices required more than the five days supported by the project. In the Expression of Interest, teachers identified their motivations for participating in this project. Teachers in the more successful teams indicated an intrinsic interest in enhancing their knowledge of ESL pedagogical practices in Science and a willingness to collaborate with others to improve students' learning.

• *Teachers' flexibility.* Individual teachers needed to be flexible, adjusting their pedagogical approaches to meet the changing needs of their students. This flexibility ranged from adjusting the sequence of lessons to allowing students to take more responsibility in planning and conducting their scientific experiments.

• *Specialised knowledge.* In the more successful projects, the Science teachers completed a professional development program called Teaching English Language Learners Across the curriculum (TELL), which provided them with a basic knowledge of strategies to support EAL/D students' learning.

OUTCOMES

The collaborative professional learning outcomes at individual schools varied. However, almost all participating teachers reported that the professional development positively impacted their knowledge of how to support EAL/D students in Science classrooms. The common themes from the interviews conducted with the teachers at the end of the project were:

• *Students' engagement.* Teachers explained that the project had an enormous impact on students' engagement. This was related to increased student teamwork opportunities and participation in hands-on activities and discussions related to the Rich Tasks. Increased engagement, in turn, led to more student-talking in the classroom and increased confidence.

• *Science learning and language.* Students' engagement also led to enhanced disciplinary knowledge and the ability to think scientifically. From a language perspective, teachers particularly commented on students' oral language and writing, including increased use of scientific terminology.

DESIGN PRINCIPLES

The figure below highlights six design principles for teachers' interdisciplinary learning that are most prominent in this case.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

ACTIVITY QUESTIONS

1. How are the highlighted six design principles enacted in this case?

2. Which other design principles are also featured in this case, and how?

3. What additional design features, not covered by the principles, are critical in this case?

4. In what ways can the ideas from this case be adapted to enhance teachers' interdisciplinary learning in your own context?

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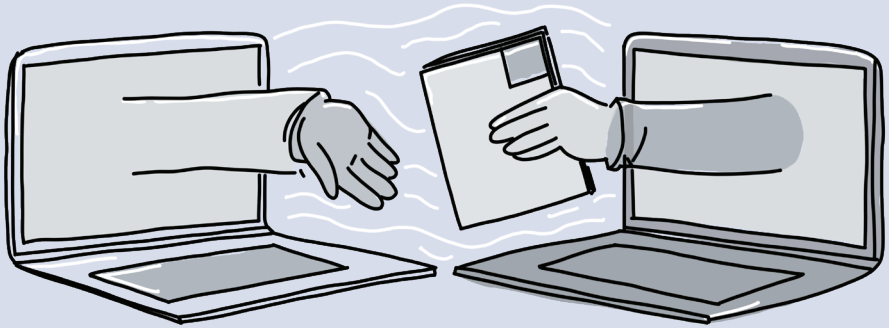
"GENAI" IN INITIAL TEACHER EDUCATION – ENHANCING STUDENT TEACHERS' INTERDISCIPLINARY EXPERTISE AND AGENCY



PRE-SERVICE TEACHERS' PROFESSIONAL INTERDISCIPLINARY LEARNING

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CONTEXT

Generative Artificial Intelligence (GenAI), such as ChatGPT, can accomplish a wide range of tasks faster and better than humans (Markauskaite et al., 2022), leading to questions of how best to integrate it into teaching and learning. While some believe that we need to embrace it, others have expressed concerns regarding its potential to pose challenges and disruption to education (Dwivedi et al. 2023). One concern is that it may deskill learners and raise ethical issues. There is also a fear that the rise of GenAI will threaten human agency, even as it is claimed to enhance human agency (Sundar, 2020), as users have little control over the responses generated by GenAI, apart from writing and revising of their prompts (Sundar & Liao, 2023). Moreover, teachers' insufficient familiarity with GenAI has been identified as a significant challenge in effectively integrating it into the classroom (Adiguzel et al., 2023).

To address these concerns, it is important to ensure that teachers are equipped with the knowledge and skills necessary for the appropriate use of GenAI in their teaching (Eke, 2023) and understand its impact on human intelligence and well-being (Markauskaite et al., 2022). It is also important to enhance teachers' interdisciplinary expertise: to integrate it with their pedagogical content knowledge and knowledge of students. This study aims to develop resources to enhance student teachers' interdisciplinary expertise in integrating GenAI into their pedagogical design. It uses a formative intervention approach which also encourages collaboration between student teachers.

AIMS AND PURPOSE

The aim is to enhance student teachers' interdisciplinary expertise in integrating GenAI into their pedagogical designs - adopting a situated and contextualized perspective on AI literacy that enables student teachers to integrate AI into some specific topics and teaching contexts (Sperling et al., 2024). This also provides opportunities for student teachers to exchange information and ideas, thereby also fostering their collaboration skills.

CAPABILITIES

The resources and activities aim to develop student teachers' interdisciplinary expertise by integrating curriculum-related, subject-content-based, ethical and professional uses of digital technologies (Falloon, 2020). Specifically, student teachers learn to use GenAI.

APPROACH

The design of this module for pre-service teachers takes a formative intervention approach, informed by Cultural Historical Activity Theory. More specifically, it is underpinned by the epistemological principle of double stimulation (Sannino, 2015). From the perspective of Cultural Historical Activity Theory, human agency refers to intentions and wilful actions, from taking initiatives to making transformations (Engeström & Sannino 2020). Originating in Vygotsky's (1987) work, double stimulation is a structured method to "actively promote the transition from the current state of affairs to a new (not yet existing) one" in which the subject is provided with a problem first and then given "active guidance towards the construction of a new means to the end of a solution to the problem" (Van der Veer & Valsiner, 1991, p.169).

Sannino (2015) has re-modelled double stimulation as a process of fostering agency with some key elements. The first element is a conflict of motives which is activated by creating a challenging or conflicting problem, which is called the "first stimulus" (Hopwood, 2022; Sannino, 2015). In this study, the first stimulus is to use an AI literacy scale (Wang et al., 2023) to raise student teachers' awareness of the need for, and issues associated with, integrating GenAI into their pedagogical design.

The second key element is the "second stimulus" which offers resources that the person can use for analysing and solving the problem (Hopwood, 2022) so that they can break away from the conflict of motives (Sannino, 2015). Agency is fostered when they cope with the problematic situation by using the second stimulus (Virkkunen & Ristimäki, 2012). In other words, the process of motive formation, sense-making and decision-making depends on the use of the second stimulus (Sannino, 2015).

This module provides a series of second stimuli for enhancing learners' agency, including the designed tasks, iterative revising prompts, evaluating responses from ChatGPT, group discussion and reflection.

KEY CONCEPTS

AI LITERACY

AI literacy combines the ideas of data science, computational thinking and multi-disciplinary knowledge (Ng et al., 2021).

AGENCY

From a Cultural Historical Activity Theory perspective, agency refers to the individual or group's wilful intention and actions in changing the situation (Sannino, 2015).

CHATGPT

ChatGPT is a specific application of generative AI developed by OpenAI, based on the GPT (Generative Pre-trained Transformer) architecture. It is designed to generate human-like text based on the input it receives, making it useful for a wide range of conversational applications. In the context of GenAI, ChatGPT exemplifies how generative models can be used for natural language processing tasks, providing users with intelligent and context-aware interactions.

DOUBLE STIMULATION

Double stimulation is a concept from Cultural Historical Activity Theory. It involves an individual being confronted with a problem (first stimulus) and then using an auxiliary means (second stimulus) to solve that problem. This process helps in the development of higher mental functions as individuals learn to use tools or signs to mediate their responses to challenges.

FIRST STIMULUS

The first stimulus, in the context of double stimulation, refers to the initial problem or challenge that an individual encounters. This is the task or situation that prompts a need for a response or solution, highlighting a gap or conflict that needs to be addressed.

GENAI

GenAI (Generative Artificial Intelligence) refers to AI systems that can generate content, such as text, images, music, or other media, often using deep learning models like Generative Adversarial Networks (GANs) or Transformers. These systems can create new, original content based on the data they were trained on, making them powerful tools for creativity and problem-solving in various fields.

SECOND STIMULUS

The second stimulus is the tools, signs, or auxiliary means that an individual uses to address the problem posed by the first stimulus. These can include physical tools, language, symbols, or any other form of mediating artifact that help the individual to overcome the initial challenge..

DESIGN AND IMPLEMENTATION

The module aims to foster open-mindedness and encourage preservice language teachers to explore beyond the given information. Its design includes three activities based on the structure of formative intervention to engage student teachers with a range of GenAI tools. These activities aim to develop their knowledge and skills in using AI for teaching. The GenAI tools involved include ChatGPT for text generation, AI image generators, and AI voice-over generators.

The 1st Stimuli	Student teachers complete the AI literacy scale and their perceptions towards ChatGPT
The 2nd stimuli Three tasks for student teachers to engage with GenAI in groups for pedagogical design.	Task 1: Student teachers use ChatGPT and AI image generator (MS Bing) to create a narrative in their target language and related images for a school newsletter to promote language learning.
	Task 2: Student teachers use ChatGPT to create a listening text in the target language and design activities for teaching listening skills.
	Task 3: Student teachers use an AI voice-over generator (Easeus.com) and ChatGPT to Create an audio file for the listening text and design communicative learning activities based on the listening text.
	Student teachers reflect in a group on their experiences of using GenAI for teaching.
New practice	Their pedagogical design task (e.g. a unit of work for teaching languages) with the record of using GenAI.

Figure 1. The design of the module and activities

Task 1 Relate to your newsletter bulletin.

Use ChatGPT to create a story to promote language learning. Work in groups of 3-4, completing the following steps and discussing each step with your group members. You can ask one group member to log in/create an account in ChatGPT and enter the prompts for Steps 2-5.

Step 1:	A general introduction to the use of ChatGPT.
Step 2:	Work in groups, one group member logs in and creates an account in ChatGPT and starts a new conversation.
Step 3: (5 mins)	In your group think about a topic or type of narrative to include in the newsletter and asks ChatGPT to create the narrative. Be specific with your prompts: • The role (e.g., you are a Year 9 student studying German as a second language) • The context (e.g., you just came back from an overseas trip in Germany) • The task (e.g., write a 150-word narrative about the most impressive event during the trip.)
Step 4: (5-10 mins)	In your group evaluates the ChatGPT-generated narrative: • Is the language appropriate for the character of the narrative? • Do the text type and language match the context? • Are the language and content suitable for the audience? • Is the narrative engaging to the potential audience? • Is the message clear to the potential audience?
Step 5: (5 mins)	Have another evaluation of the ChatGPT-generated narrative. If your group is not happy with the product, repeat Step 3 using as many prompts as needed and finalise the narrative.
Step 6: (10 mins)	You could consider providing an image generated by AI for the narrative. • Microsoft Bing Image Creator https://www.bing.com/images/create?FORM=GDPGLP • Skybox (3D image generator; 15 images for free) https://skybox.blockadelabs.com/ • Midjourney (need to pay)
Step 7:	Individually create and finalise a narrative to include in the newsletter.

Note: Each group member can copy the conversation thread in their ChatGPT for this task and save for future improvement and use.

Figure 2. Task 1 - Creating a narrative in target language

Task 2 Create a listening text and activities for the Stage 6 language course.

Use ChatGPT to create a text in the target language for teaching listening skills. Work in pairs/groups of the same language area, completing the following steps and discussing each step with your group members. **You can ask one group member to log in to ChatGPT and start a new conversation.**

Step 1	In your group, think about a topic and a text type for as a listening text for Stage 6 students enrolled in the continuers course. Ask ChatGPT to create the text in your target language.
Step 2 (5 mins)	Be specific with your prompts: • The topic and text type (e.g., create a conversation between two secondary students discussing a new movie) • The language and word count/length (e.g., Japanese; refer to the HS examination specification and past HSC paper regarding the length)
Step 3 (10 mins)	In your group evaluate the ChatGPT-generated text: • Is the language appropriate for the Stage 6 learners? • Does the language in the text match with the text type and the context? • Is the language accurate? • Is the narrative engaging to the potential audience? • Based on the evaluation, revise the prompts for a revised text
Step 4: (5 mins)	Have another evaluation of the ChatGPT-generation narrative. If your group is not happy with the product, repeat Step 2 using as many prompts as you want and finalise the narrative.
Step 5: (5 mins)	In your group, ask ChatGPT for some ideas about the activities to teach listening based on the finalised text.
Step 6:	In your group, evaluate whether the activities generated by ChatGPT target the skills assessed in the HSC listening section. If not, revise the prompts aiming to generate activities that target the skills.
Step 7:	Individually create a listening text and finalise the design of activities for teaching listening.

Note: Each group member can copy the conversation thread in their ChatGPT for this task and save for future improvement and use.

Figure 3. Task 2 - Creating a listening text in target language

Task 3 Create oral communication activities for the Stage 6 language course

Collaborate in language-specific pairs/groups and utilise AI voice-over software to generate oral text. From here, utilise ChatGPT to create activities that encourage communication in the target language. Complete the following steps and discuss each step with your group members. **You can ask one group member to log in to ChatGPT.**

Step 1: (15 mins)	Based on the listening task you created in Task 2, use an AI voice-over generator software to generate the audio file of the listening texts. The AI bots can speak with different accents and dialects in the target language. In your group, decide which accent you want to choose and justify your choice.
Step 2: (5 mins)	Using the listening texts as the material, ask ChatGPT to generate ideas for learning activities to practice students' communication skills in the target language. Be specific with your prompts, such as: • The topic • The key language skills and knowledge that will be involved • Any specification for the text type if applicable
Step 3: (10 mins)	In your group evaluate the ChatGPT-generated text: • Are the activities appropriate for the Stage 6 learners? • Can they practice oral communication based on HSC oral exam criteria? If your group is unhappy with the product, adjust and revise the prompts as needed.
Step 4: (5 mins)	In your group, evaluate whether the activities generated by ChatGPT target the skills assessed in the HSC oral exam. Select the three (3) best activities and justify your choice.
Step 5: (5 mins)	Ask ChatGPT for ideas of differentiation. Select the three (3) best activities for the students in the beginners, continuers, and extension courses respectfully. Note: For the four (4) Asian language, you could differentiate for the language in context course.
Step 6:	Individually create a listening text and finalise the design of activities for teaching both listening and speaking.

Note: Each group member can copy the conversation thread in their ChatGPT for this task and save for future improvement and use.

Figure 4. Task 1 - Creating oral communication activities in target language

ASSESSMENT

For assessment student teachers submit their created resource and their individual reflection on 1) how they used GenAI; 2) what they learnt about the use of GenAI in future practice; 3) what they see as the biggest challenges of using GenAI for creating teaching resources for their teaching.

TOOLS AND RESOURCES REQUIRED

The tools and resources used in the activities are:

Online resources:

- ChatGPT 3.5
- Bing Image creator: https://www.bing.com/images/create?FORM=GENILP
- AI voice-over generator https://multimedia.easeus.com/ai-voice-generator

REFLECTIONS AND LESSONS LEARNT

MACRO LEVEL

- *Curriculum integration.* These activities were integrated into the existing languages curriculum unit and conducted during class time. Therefore, the tasks were selected to fit the existing curriculum structure, topics and their sequence.
- *Use GenAI for translating across different disciplines.* Future activities could include the topic of Content and Language Integrated Learning (CLIL), in which pre-service teachers need to design and develop resources to integrate language learning with another subject. For example, if the concept from another subject needs an explanation, they could use GenAI (e.g., ChatGPT) to explain and translate the concept into the target language.

MESO LEVEL

- *Links between tasks.* The first task served as a useful first experience of GenAI capabilities for those pre-service teachers who had not used GenAI tools before. However, there could have been a closer link between the first task and the other two tasks.
- *A balance between group work and individual work when interacting with GenAI.* If some group members were unfamiliar with drafting prompts, composing all the prompts took a long time. However, most student teachers said that they learned a lot from group discussions. In the future, the design could include both group discussion and individual work. For example, the group can discuss the prompts and evaluation of the product and then finalise the task using GenAI individually.

MICRO LEVEL

- *Adequate time to complete the tasks.* Each activity involves 2-3 hours as student teachers need time for discussion at the end of the task. If they want to continue the discussion after the class, a discussion thread could be created on their online learning site.
- *Student teachers' engagement.* While student teachers were engaged in the activities and saw relevance to their future professional work, this could be further enhanced by asking student teachers to select the topics that fit their learning interests and needs. Student teachers' self-identified topics can enhance their motivation and agency in learning.

DESIGN PRINCIPLES

The figure below highlights five design principles for teachers' interdisciplinary learning that are most prominent in this case.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

ACTIVITY QUESTIONS

1. How are the highlighted five design principles enacted in this case?

2. Which other design principles are also featured in this case, and how?

3. What additional design features, not covered by the principles, are critical in this case?

4. In what ways can the ideas from this case be adapted to enhance teachers' interdisciplinary learning in your own context?

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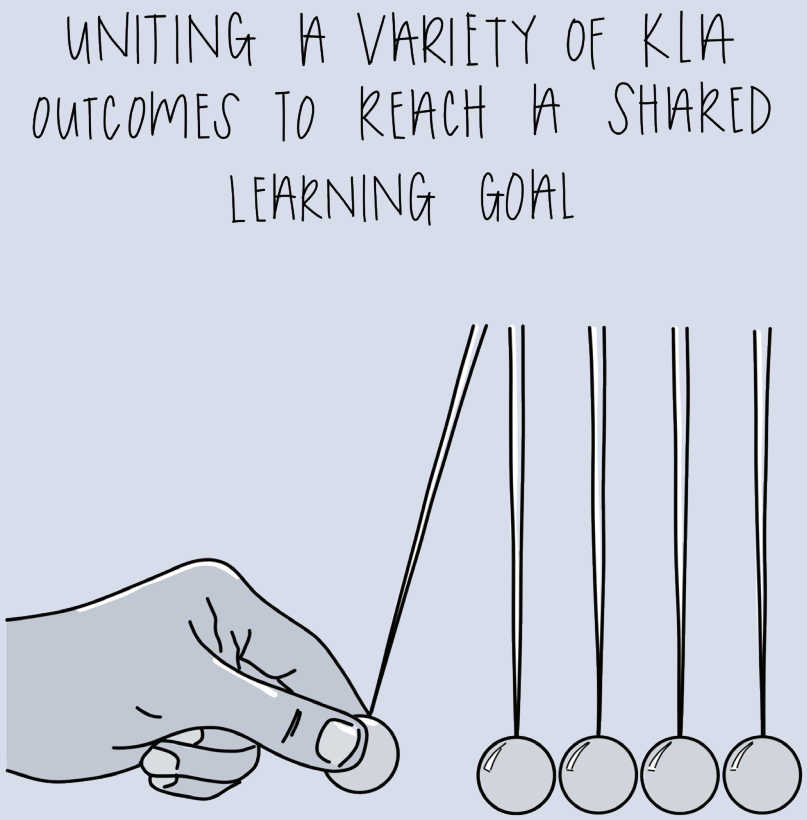

IN-SERVICE TEACHERS' PROFESSIONAL
INTERDISCIPLINARY LEARNING

NICOLA CURRIE
NSW DEPARTMENT OF EDUCATION
CLASSROOM TEACHER

PREAMBLE

The high school environment differs from the primary school environment in that there are subject-specific teachers who are hired for their expertise in particular learning areas. In the primary school, teachers are trained to work across a broad range of areas, deftly moving between phonics, division, fractions, inferences, gross motor skill development – the list goes on. Because high school teachers are trained in a particular discipline, this inevitably leads to a situation where there are a lot of experts with a particular focus.

Problems can arise when students are unable to make the (necessary) links between different subjects and their eventual place in the world. There is a tendency for students to think of learning as being in 60-minute chunks. They view their subject learning as being discrete. As adults, we know that this is not the way the world works. Therefore, it would be remiss of us as a profession not to provide the students with an educational outlook that shows the interrelated nature of how real life actually works.

This leads us to the urgent realisation that interdisciplinarity is relevant in society. We are teaching the students before us with little to no realisation of what their future jobs/professions will be because they have not yet been invented. We do know that their future will be dependent on creative and critical thinking; will almost certainly contain collaborative elements drawing on strengths and expertise from others; and will require a healthy dose of problem-solving.

Whilst some students will be able to join the pieces of this puzzle on their own, most students would benefit from a chance to explore learning opportunities that bring all these elements together in order for them to make connections more effectively in the future. This is where interdisciplinary learning comes in.

Much of my practice is completed using an interdisciplinary approach, combining many of the key learning areas into one teaching topic. Topics I have taught in the high school environment include Japan; Ancient Egypt; Natural Disasters; The Living World; The Vikings; Scotland & Australia. These have all utilised English, History, Geography, Science and Mathematics.

I developed this resource with two aims:

- To present an example explaining and illustrating my thinking and practices in developing and teaching interdisciplinary units of work while collaborating with teachers from different faculties to enhance learning opportunities for students.
- To articulate some general principles that teachers new to interdisciplinary ways of working might find helpful. I also present some ideas that could assist teacher educators in helping pre-service teachers prepare for interdisciplinary teaching.

I start with the example of a unit of work called "Representing Facts – the truth behind data collection". After, I present my usual thought process when planning and preparing an interdisciplinary unit of work, regardless of the topic or the learning gap to be filled. It is my intention that the presented exemplar and template would allow beginning teachers to identify ways to work in an interdisciplinary manner with colleagues from other faculties. Therefore, I made my thinking transparent.

CREATING A UNIT OF WORK "REPRESENTING FACTS – THE TRUTH BEHIND DATA COLLECTION"

CONTEXT

Through an informal conversation with one of my colleagues, I realised that in our school, graphs were being explicitly taught in Mathematics in Year 8, while graphs were being used as a data collection method in Science in Year 7. This identified a potential gap in student learning. Knowledge was required in Year 7 but was only explicitly taught in Year 8. From here, I looked at the outcomes of a variety of subjects to identify where graphs were used and assembled an interdisciplinary unit of work examining the use of graphs and data collection.

AIMS AND PURPOSE

For the purposes of this unit of work, I decided to work on the capability of critical and creative thinking and the priority of civics and citizenship. This was my starting point. What specific skill do I want the students to learn? Through exploring this topic, I want them to be informed, global citizens who can think critically about the information with which they are presented.

In this unit I wanted to join the learning that is happening in different subjects, but at some point, when pulling any unit of KLA outcomes together, it is important to ask why? And this is what brings me to the core of interdisciplinary learning. Why do it? What do we want the students to realise? For graphs, I want the students to be able to see bad data as well as good; for them to be informed global citizens. I want the teachers to make the most of their teaching time so that they can really get into the subject matter. By sharing the teaching of graphs across multiple subjects, the mental load is lessened by everyone involved, and the students come away with a more rounded understanding of how graphs and data are used within the modern world. Different subjects use graphs for different reasons, but all want their students to recognise information and make informed decisions.

According to the rationale of the NSW Mathematics syllabus, it is "through the study of mathematics, students apply their knowledge and skills to deepen their understanding of the world". This is, at its core, the goal of this interdisciplinary unit of work. To elaborate, the aim of this unit is to provide students with an awareness of the use of graphs and statistical data as a source of information, and to also provide them with knowledge of how this data format can be skewed to misrepresent evidence and information.

OUTCOMES

For Kindergarten to Year 10, educational programs are based on the outcomes of syllabuses. The content provides detail about how the outcomes can be interpreted and used, and the intended learning appropriate for the stage.

Relevant teaching outcomes for this topic:

- MA4-RAT-C-01 a student solves problems involving ratios and rates, and analyses distance-time graphs.
- MA4-LIN-C-01 a student creates and displays number patterns and finds graphical solutions to problems involving linear relationships.
- MA4-DAT-C-01 a student classifies and displays data using a variety of graphical representations.
- SC4-WS-05 a student uses a variety of ways to process and represent data.
- SC4-WS-06 a student uses data to identify trends patterns and relationships and draw conclusions.
- SC4-DA1-01 a student explains how data is used by scientists to model and predict scientific phenomena.
- GE4-7 a student acquires and processes geographical information by selecting and using geographical tools for inquiry.
- GE4-8 a student communicates geographical information using a variety of strategies.
- EN4-URC-01 a student identifies and explains ways of valuing texts and the connections between them.
- EN4-URB-01 a student examines and explains how texts represent ideas, experiences, and values.
- HT4-3 a student describes and assesses the motives and actions of past individuals and groups in the context of past societies.
- HT4-6 a student uses evidence from sources to support historical narratives and explanations.

APPROACH

The framework for this unit of work was developed by looking through a mathematical lens to provide opportunities for students to engage in different ways to present data. Running parallel to this would be the scientific principles of data collection that helps to explain, and allow students to better understand, phenomena in the natural world. Once students are confident in the different types of graphs and data collection, then it would be natural to present them with skewed data sets through the lens of other subjects, perhaps History and Geography. How do governments present data in a way to further their own agendas? How has data been presented in the past to misrepresent events?

There are several layers to this interdisciplinary resource; at its core lies the data tabulations of Mathematics and Science. In Mathematics, graphs are used to formulate specific conclusions, particularly as students progress through the high school curriculum. In Science, the use of graphs is primarily for identification of trends and prediction, that is to hypothesise and infer what might happen in the future. This is similar, almost parallel to its use in the geographical context. In the English context, graphs can be used to plot the emotions of a character or the build-up of tension within a text. The waters become muddier when graphs and data are used in the subject of History. In History, students begin to see the nuances of data representation, and more importantly, misrepresentation, and it is only with a solid grounding and knowledge of how graphs work that students will be able to see how particular data is being presented to them.

DESIGN AND IMPLEMENTATION

What follows is an outline of a ten-week unit of work for Year 7 undertaken between the Mathematics, Science, HSIE (Human Society in its Environment – i.e. History and Geography), and English faculties. The project can be changed to suit the school context, the cohort to whom it is being presented, the urgency of a particular societal problem in the local context, etc.

Week 1: Introduction to Graphs and Data in Mathematics, Science and Geography

Mathematics: Introduce different types of graphs (bar graphs, pie charts, line graphs) and basic data interpretation.
Mathematics (continued): Practise creating and interpreting graphs related to local, geographical information, e.g. the number of parks, density of local suburbs.
Science: Discuss the importance of collecting data in scientific research and examine several different data collection methods to ascertain which one would suit particular data sets.
Geography: Explore how graphs can represent geographical data like population distribution, climate patterns, etc.

Week 2: Further exploration of Graphs and Data in Mathematics, Science and Geography

Mathematics: Continue exploring different types of graphs and data interpretation.
Science: Include data collection within practical science experiments in the laboratory or classroom. Continue to discuss the importance of collecting data in scientific research.
Geography: Explore scale and magnitude when dealing with large data sets and examine how these can be represented in straightforward terms.
Mathematics: Practise creating and interpreting graphs related to Science, or even PDHPE, information. One example could be performing a simple experiment testing the students' heart rate before, during and after exercise and tabulating these results in the most efficient fashion.

Week 3: Graphs in History

History: Analyse historical events using graphs to visualize trends over time. Examples could be population growth of specific countries over specific centuries.

History (continued): Examine concepts such as correlation and causation and begin to introduce the idea that data can be skewed to highlight particular agendas.

Mathematics: Create timelines and line graphs to plot historical data using the information that the students are currently learning in History. For example, Middle Ages, Ancient Egypt, and Ancient China.

Science: Examine parts of the history of scientific data collection, focusing on early vaccination information, or other relevant historical, public health data, e.g. the outbreak of the plague in Sydney in the early part of the 20th century.

Week 4: Graphs in English Literature

English: Once students have begun to exhibit fluency within the use of graphing and plotting, introduce the use of graphs to analyse characters' emotions or story arcs within literature texts. An example could be the class novel. Graphs could be used in a broad fashion to summarise an aspect of the story so far, like terror, love, action. They could be used to follow a character's emotions within a specific section of text, creating a more potent and nuanced data set.

Mathematics: Practice creating and interpreting graphs based on particular aspects of something that the students show specific interest in, e.g. intensity of action scenes within a Marvel movie.

Science: Present the students with data and ask them how best to demonstrate it in a usable format. Discuss the various possibilities that the students propose.

Week 5: Further Data Collection in Science and Mathematics Experiments

Science: Conduct more experiments, depending on the Science scope and sequence, using the collected data to create graphs for analysis.

Mathematics: Examine how to best tabulate the data that arises from chance and probability experiments, successfully integrating different branches of the Mathematics curriculum. Interpret the data collected and create appropriate graphs.

Geography: Continue to develop skill sets in data collection.

Week 6: Interpreting Data in Current Events (Geography and Science)

Geography: Analyse current geographical data through graphs (e.g., climate change trends).

Science: Discuss the use of data in addressing current scientific challenges.

English: Looking at a topical news story, analyse the data and graphs that are being shown in the newspapers or on the internet to show the information, to ascertain the relevance or bias of the information being shown.

Week 7: Analysing Historical Trends (History and Mathematics)

History: Explore historical data using graphs and identify trends. This is an opportunity for students to rise through the Blooms' Taxonomy framework and allows them to delve further into graphic analysis.

Mathematics: Apply statistical concepts to analyse historical data patterns using the topics that they are currently learning about in History.

Science: Continue developing student knowledge of the nuances of plot graphs versus bar graphs and when each is important. Plotting requires a high level of accuracy that students must be explicitly taught.

Week 8: Visualising Themes in Literature (English and Mathematics)

English: Using a piece of creative writing that the students have produced or by analysing a peer's work, create graphs to represent themes or motifs.

Mathematics: Analyse and interpret increasingly complex data sets through different mathematical concepts and graphs.

Weeks 9 & 10: Portfolio Preparation and Culminating Project
All subjects: Begin the task of preparing a portfolio. Include the various data collections covered in the term and include ways for students to produce a personal project that highlights their knowledge of what they have learned throughout the topic. Students complete their final project that incorporates elements from all subjects. They collect data, create graphs, analyse trends, and present their findings in a cohesive manner on a topic of their choosing.

TOOLS AND RESOURCES REQUIRED

Links

Common graphs in Geography
https://education.nsw.gov.au/teaching-and-learning/curriculum/hsie/hsie-curriculum-resources-k-12/hsie-7-10-curriculum-resources/common-graphs

Vocabulary and terminology in Geography
https://education.nsw.gov.au/teaching-and-learning/curriculum/hsie/hsie-curriculum-resources-k-12/hsie-7-10-curriculum-resources/geography-terminology-7-10

REFLECTION

This unit provides a comprehensive approach to teaching graphs and data while integrating multiple subjects, fostering cross-curricular connections, and enhancing students' understanding of real-world applications of these concepts. The unit focuses on three or four subjects per week, but a bolder approach could be to incorporate more subjects per week to better achieve mastery. When building my own inter-disciplinary units, I aim for at least six integrated lessons in a week. To be clear, the integration of different subjects does not mean it is to the exclusion of the other parts of the curriculum. Twenty minutes of an hour-long lesson can be enough to integrate thoughts and ideas within the students' minds and allow them to see links within their learning.

Crucially, this particular unit of work can exist within the school's already established curriculum. All the subjects mentioned in this resource use graphical interpretations to explore and teach within their subject, with the possible exception of English. This interdisciplinary unit of work could be designed to sit alongside established curricula where need be, and indeed this could be an "entry-level" approach if some teachers felt vulnerable about joining forces. When preparing the unit of work, teachers could look at their existing programs and see where this combined, interdisciplinary unit would fit in.

Mathematics, Geography, and Science would take the reins on this topic, directly teaching the different charts and graphs that are most suitable in certain situations. History and English's involvement would come slightly later, looking at interpretation, inference, and bias. The culmination would be students who are more informed about looking at data (remembering there is a misconception that because it is in a graph it is "easier" to read) and being able to make more informed decisions when considering primary and secondary sources.

NOTES ON USING THIS EXEMPLAR FOR TEACHERS' PROFESSIONAL LEARNING

PURPOSE

Interdisciplinary learning is an approach to education that integrates knowledge, skills, and concepts from multiple disciplines or subject areas. It encourages students to make connections between different areas of study and to see the relevance and interconnectedness of various fields. Interdisciplinary learning can help students develop a more holistic understanding of complex issues and better prepare them for real-world challenges that often require a combination of expertise from different disciplines. It can also promote critical thinking, creativity, and problem-solving skills.

In an interdisciplinary learning environment, teachers collaborate to design learning experiences that cut across traditional subject boundaries, fostering a more comprehensive and integrated approach to education.

Therefore, the capabilities that teachers need involve the use of interdisciplinary pedagogies; the design of lessons and resources for interdisciplinary learning; and the employment of collaborative ways of working. Learning through collaboration and developing a concrete, interdisciplinary unit should help teachers to see the direct relevance of interdisciplinary practices in their professional work

CAPABILITIES

By following this model for interdisciplinary planning and work, pre-service teachers can learn to:

- Collaborate with other subject teachers
- Take a student-led approach
- Design creative and hands-on learning activities
- Construct important "topic" resources that can be simply taken "off-the-shelf" and revitalised to suit the needs of the current cohort.

This way of working also allows pre-service teachers or newly graduated teachers to meet the requirements of the NSW Graduate Teacher Standards summarised in Figure 1.

1.2.1 Demonstrate knowledge and understanding of research into how students learn and the implications for teaching.

2.1.1 Demonstrate knowledge and understanding of the concepts, substance and structure of the content and teaching strategies of the teaching area.

2.2.1 Organise content into an effective learning and teaching sequence.

2.3.1 Use curriculum, assessment and reporting knowledge to design learning sequences and lesson plans.

2.5.1 Know and understand literacy and numeracy teaching strategies and their application in teaching areas.

3.1.1 Set learning goals that provide achievable challenges for students of varying abilities and characteristics.

3.2.1 Plan lesson sequences using knowledge of student learning, content, and effective teaching strategies.

3.3.1 Include a range of teaching strategies in teaching.

3.4.1 Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning.

4.1.1 Identify strategies to support inclusive student participation and engagement in classroom activities.

4.2.1 Demonstrate the capacity to organise classroom activities and provide clear directions.

5.1.1 Demonstrate understanding of assessment strategies, including informal and formal, diagnostic, formative and summative approaches, to assess student learning.

6.3.1 Seek and apply constructive feedback from supervisors and teachers to improve teaching practices.

Figure 1: Related standards for NSW Graduate Teachers (NSW Government, 2024b)

KEY CONCEPTS AND DEFINITIONS

Teachers working on developing an interdisciplinary unit of work should be familiar with the key curriculum terminology.

CAPABILITIES AND PRIORITIES

Formerly "Learning Across the Curriculum", the capabilities in the NSW curriculum encompass the knowledge, skills, attitudes, and behaviours that assist students to live and work successfully. The priorities in the NSW curriculum develop students' understanding of communities, contemporary issues, and the world around them.

The **capabilities** are:
Literacy
Numeracy
Digital literacy
Critical and creative thinking
Ethical understanding
Intercultural understanding
Personal and social capability.

The **priorities** are:
Aboriginal and Torres Strait Islander Histories and Cultures
Asia and Australia's engagement with Asia
Sustainability
Civics and citizenship
Diversity and difference
Work and enterprise.

RATIONALE

The rationale is the reasoning behind why we are teaching students about a particular learning area and/or focus.

KEY LEARNING AREA (KLA) OUTCOME

A statement of what a learner is expected to achieve at the completion of a unit of study.

UNIT OF WORK

A unit of work is a plan of the intended teaching and learning for a particular class for a particular period of time. Units of work are part of the planned sequence for teaching the outcomes and/or content of the NSW syllabuses. The duration of a unit of work could be for several weeks, a term or a semester. A unit of work provides learning experiences for students. The organisation of the content in a unit may vary according to the school, the teacher, the class, and the learning environment (NSW Government, 2024a).

SCOPE AND SEQUENCE

A scope and sequence is a summary of what is to be taught, the sequence in which it will be taught and the syllabus outcomes that may be addressed in the intended learning. Scope and sequences are flexible and fluid documents. They provide a brief overview of the key concepts and ideas addressed in a learning and teaching program for an individual stage or year. There will be variations in scope and sequences arising from the differences in school contexts, student cohorts and syllabus requirements (NSW Education Standards Authority, 2024).

APPROACH: A MODEL FOR CO-CREATING INTERDISCIPLINARY UNITS OF WORK

In a practical sense, how could teachers begin to build a unit of work that pulls together a variety of KLA outcomes for the benefit of their students? Most of these design decsisions are at the Meso level but they inevitably extend to Macro macro and Micro considerations.

MACRO LEVEL

- There are several starting points. As in the case with this interdisciplinary unit of work about graphs, a starting point could be the identification of a learning gap in your school context. An alternative pathway could be to identify a specific capability and/or priority that holds importance to you as a teacher.
- Teachers would begin by volunteering for this project – it will be more of a challenge if the participants are forced – and will arrange to meet to collaborate a series of lessons that will sequence the knowledge for their students.

MESO LEVEL

- Write a rationale about why this is an important skill to be teaching/learning. NSW curriculum syllabuses all contain succinct rationales about why they exist. Do not reinvent the wheel. Borrow from the rationales that exist and remember that the rationale explains your purpose.
- Scour the NSW syllabuses for relevant outcomes. As this is a group project between different faculties, it should be easier to spread the load and have each of the subject specialists bring their relevant outcomes to the table.
- It is natural for one subject to "take the lead". For Ancient Egypt, History begins the topic. For Japan, Geography is where we begin. For the Living World, Science is the driver. This does not mean that these teachers are the only ones teaching the topic; rather, one subject introduces the topic, and everyone follows that lead.
- Collaboratively, prepare a series of lessons and an assessment that can encompass the outcomes and capability/priority that you have identified. Allow for pre- and post- testing; include a number of direct instruction lessons to build skillset and mastery; and culminate in an assessment that can bring together all of the elements in the topic. Bear in mind that assessment can and should be formative where possible and that a portfolio of learning is often a more appropriate method of student learning than anything summative.
- Team-teach wherever possible. Combine subjects within different activities and lessons. Use each other's strengths.

MICRO LEVEL

- At the end of the unit (and throughout) reflect on what worked, what didn't, and how you adapted the unit to allow for students' interests and needs.
- Think what you gained from this experience and learnt. Do not forget about your own passions and interests.
- Coming back to the first point, I would go so far as to say that you should select something that it is important to you as a person. If it is important to you, you will be passionate about ensuring that you are working hard to embed this capability or priority at every opportunity.

ASSESSMENT

In the context of pre-service teacher education, the assessment could take the form of a group presentation of teachers' interdisciplinary mini unit of work. The goal of such assessment is to assist pre-service teachers in learning how to become interdisciplinary practitioners.

The assessment could involve:

- Forming groups of four or five pre-service teachers from different disciplines.
- Articulating a skill that pre-service teachers want high school students to achieve.
- Collaboratively planning a series of activities between the different KLAs incorporating a one-week unit of work comprising a rationale, outcomes, and lessons, and culminating in a class-based assessment activity.
- Delivering a presentation of their unit to their peers.

By combining their KLA outcomes, the pre-service teachers should be able to see that they all achieve more when they combine their individual subject strengths instead of being 'siloed' in their own individual faculties.

DESIGN PRINCIPLES

The figure below highlights six design principles for teachers' interdisciplinary learning that are most prominent in this case.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

ACTIVITY QUESTIONS

1. How are the highlighted six design principles enacted in this case?

2. Which other design principles are also featured in this case, and how?

3. What additional design features, not covered by the principles, are critical in this case?

4. In what ways can you adapt the ideas from this case to enhance teachers' interdisciplinary learning in your own context?

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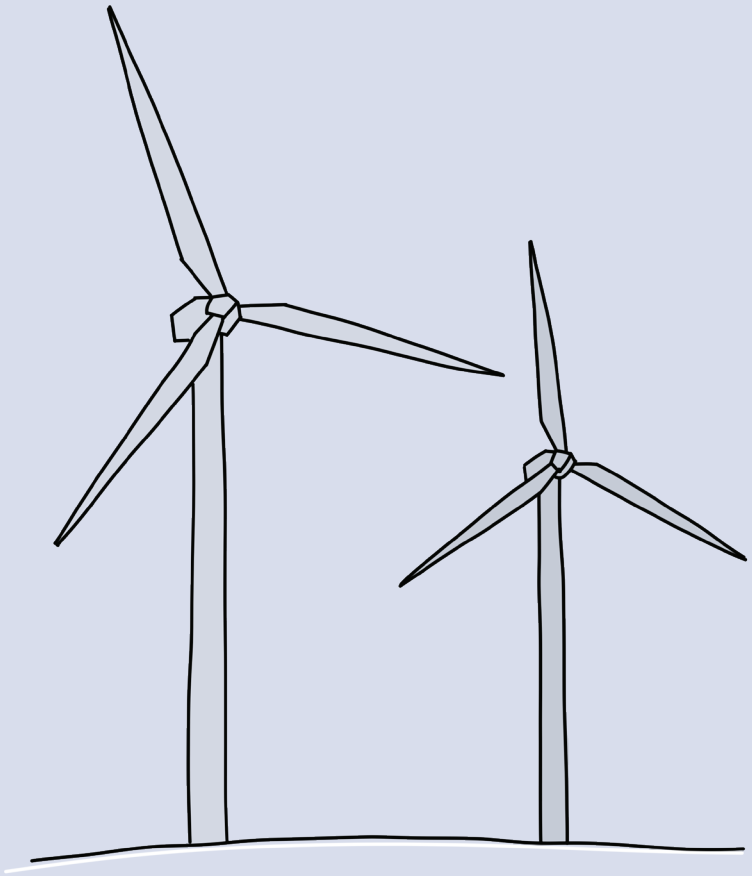
EXPLORING WIND TURBINES



IN-SERVICE TEACHERS' PROFESSIONAL INTERDISCIPLINARY LEARNING

MARTIN LEVINS
UNIVERSITY OF NEW ENGLAND

PREAMBLE

In this resource, I describe a case of interdisciplinary professional learning through collaboration with my colleagues teaching other subjects for the students in the same cohort. Through this case study, I will illustrate how interdisciplinary professional learning can be a part of ongoing teaching practices. This example illustrates possibilities that other school teachers may also see in their classroom and decide to explore. The case study explores the topic of wind turbines.

CONTEXT

The project took place in a combined year 3/4 classroom with a diverse student body, including 30% Aboriginal and 30% Ezidi refugee students. The educational approach at this school integrates thematic learning centred around "the book of the term". In this instance, the book was "The Boy Who Harnessed the Wind", which tells the true story of William Kamkwamba, a young boy from Malawi who built a wind turbine from scrap materials to provide electricity for his village after being forced to leave school.

The book's narrative, highlights William's determination and ingenuity. At 14, unable to afford school, William borrowed books from a small library, discovering one about energy that featured a wind turbine on the cover. Intrigued by the science of electricity, William decided to build a windmill using scrap metal, old bicycle parts, and wood. Despite ridicule and physical exhaustion from his daily work in the fields, he successfully built his own windmill.

This story resonated strongly with the Ezidi students when they learned that the earliest windmills, developed between 700–900 AD, originated in Persia (modern-day Iran), which is closely tied to their heritage. This historical connection added a personal and cultural dimension to the project, enriching the learning experience for the Ezidi students and fostering a deeper engagement with the subject matter.

The exploration of wind turbines through the lens of William Kamkwamba's story offers a rich, interdisciplinary educational opportunity. The project intersects various fields of study, including:

Science and Technology: Students learn about renewable energy, the mechanics of wind turbines, and basic principles of electricity and engineering.

History and Culture: The historical context of windmills in Persia provides a connection to the students' cultural heritage, enriching their understanding of technological evolution and cultural contributions.

Storytelling: Using a compelling narrative as the foundation for the project engages students emotionally and intellectually, enhancing their reading and comprehension skills.

Social Studies: The project encourages discussions about perseverance, innovation, and the socio-economic challenges faced by different communities globally.

The example demonstrates how a thematic, interdisciplinary approach to learning, centred around a culturally resonant narrative, can enhance engagement and educational outcomes in a diverse classroom.

AIMS AND PURPOSE

The aims and purpose of this case study are to document and analyse the outcomes of a multidisciplinary educational unit focused on wind turbines, delivered to a diverse class of year 3/4 students. The specific goals and objectives of this recount are:

Interdisciplinary Integration: To detail how the unit successfully integrated various subjects including Science, Design, Digital Solutions Development, and Aboriginal and Torres Strait Islander history and cultures, demonstrating the effectiveness of an interdisciplinary approach in primary education.

Inclusivity and Achievement: To highlight how the unit was designed to be achievable and valuable for all students, particularly addressing the needs of a diverse student body with 30% Aboriginal and 30% Ezidi refugee students. The aim is to showcase strategies that made the content accessible and engaging for all learners.

Collaboration and Relationship Building: To illustrate how the unit fostered collaboration among students and between teachers from different disciplines. It shows how this collaborative approach built relationships and enhanced the learning experience.

Language Development: To document the strategies used to expand students' language abilities, particularly for those learning English as an Additional Language or Dialect (EAL/D). It provides insights into how language development can be effectively integrated into STEM education.

Cultural Relevance: To emphasise the importance of cultural relevance in the curriculum. It explores how incorporating students' cultural backgrounds, such as the historical significance of windmills in Persia for Ezidi students, enhanced engagement and learning outcomes.

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Professional Development: To provide an account of how the unit served as a context for collaborative professional learning among teachers. It highlights the benefits of interdisciplinary collaboration for teacher development and curriculum planning.

Contextual Learning: To connect the unit to the local context of the school, situated in a NSW Renewable Energy Zone. It shows how focusing on wind turbines made the learning experience more relevant and impactful, linking classroom activities to real-world applications and the local community's emphasis on renewable energy.

Through recounting this unit, the case study aims to provide valuable insights into effective teaching strategies for diverse classrooms, the benefits of interdisciplinary and collaborative approaches, and the importance of culturally relevant and contextually meaningful education.

APPROACH

The design of the unit was guided by a blend of constructivist and culturally responsive pedagogies. Constructivism emphasises hands-on, activity-based learning where students construct their own understanding and knowledge through experiences and reflections. Culturally responsive pedagogy values and incorporates students' cultural backgrounds and experiences into the learning process, fostering a more inclusive and engaging educational environment.

Guided, Hands-On Learning: The approach centred on age-appropriate, guided collaboration among students. They were provided with materials such as paper roll inserts, scissors, pop sticks, hot glue, a DC hobby motor with a stand, and the necessary code to measure electricity generated by their wind turbines. This hands-on, experiential learning allowed students to engage deeply with the concepts.

Simplification of Complex Concepts: To ensure accessibility, complex technical terms like "voltage" were omitted. Instead, the focus was on practical outcomes, with the micro:bit giving a simple three-digit number representing the electricity generated. This approach kept the learning process straightforward and focused on tangible results, which is appropriate for the age group.

Iterative Design and Prediction: After the initial construction of the wind turbines, students were encouraged to modify the blades and predict the impact on electricity generation. This iterative process of hypothesis, testing, and observation helped students develop critical thinking and problem-solving skills.

Cultural Integration: The project incorporated elements of Aboriginal and Torres Strait Islander history and cultures by introducing the students to the design of the boomerang, likening its shape to a wing, and shared the story of David Unaipon, an Aboriginal Ngarrindjeri polymath who applied the concept of a boomerang to early helicopter design. This cultural reference aimed to connect students' learning to their heritage and highlight the contributions of Indigenous Australians to science and technology.

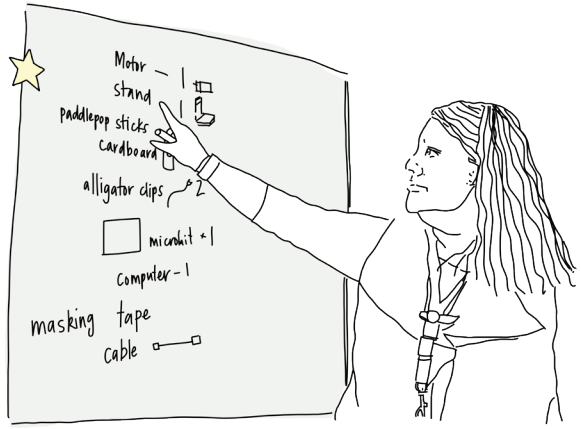

Figure 1. The STEM lead teacher going through the materials list.

KEY CONCEPTS

CONSTRUCTIVISM

Constructivism is a learning theory that suggests learners actively construct their own understanding and knowledge of the world. In practice, constructivist approaches encourage educators to facilitate learning experiences where students engage in authentic tasks, explore concepts through inquiry, and construct meaning through active participation.

CONSTRUCTIONISM

Constructionism extends constructivist principles by emphasising the creation of tangible products or artefacts as a means of learning. It posits that learning is enhanced when students engage in constructing physical objects or digital artefacts that are meaningful and shareable. In educational settings, constructionism encourages hands-on, project-based learning where students design, build, and reflect on their creations.

EXPLICIT TEACHING

Explicit teaching involves direct instruction where educators provide explicit explanations, demonstrations, and guided practice to support students in acquiring specific knowledge or skills.

MICRO:BIT

A micro:bit is a programmable microcontroller designed for educational purposes. It includes various built-in features such as LEDs, buttons, sensors, and wireless communication capabilities. It allows students to learn coding, physical computing, and electronics through hands-on projects.

SOLO TAXONOMY

The Structure of Observed Learning Outcomes (SOLO) Taxonomy is a model that categorises levels of understanding or performance in learning tasks. It provides educators with a framework to assess and scaffold students' learning progress from simple to more complex levels of understanding or performance.

TEACHER FLEXIBILITY

Teacher flexibility refers to the adaptability of educators in their instructional approaches and methods, ranging from teacher-directed to student-centred learning environments.

UNIVERSAL DESIGN FOR LEARNING (UDL)

Universal Design for Learning is a framework for designing educational environments and experiences that are accessible and effective for all students, including those with diverse learning needs.

DESIGN AND IMPLEMENTATION

The design and implementation of the unit involved a series of structured activities that engaged students in hands-on, interdisciplinary learning. Each activity was crafted to integrate multiple learning areas, providing a comprehensive and cohesive educational experience.

1. Constructing the Wind Turbines

Activity: Students constructed wind turbines using paper roll inserts, pop sticks, and a DC hobby motor with a stand. Learning Outcomes:

- English: Writing and following procedural texts to guide construction.
- Science & Technology: Understanding basic principles of engineering and material jointing.
- Engineering: Applying basic engineering techniques to assemble the turbine.

2. Coding and Testing

- Activity: Students coded a microcontroller (micro:bit) to measure and display the amount of electricity generated by their wind turbines. Learning Outcomes:
- Science & Technology: Learning fair testing principles by measuring and comparing electricity production.
- Coding: Writing code to read and display data from the microcontroller.

3. Iterative Design and Modification

Activity: After the initial construction, students modified the shape of the turbine blades to optimize electricity generation. Learning Outcomes:

- Engineering: Understanding how the shape of turbine blades affects efficiency.
- Science & Technology: Applying fair testing by comparing the electricity output before and after modifications.

4. Cultural Integration and Historical Context

Activity: The Aboriginal Education Officer discussed the design of boomerangs and their aerodynamic properties, relating this to the design of turbine blades. Students learned about David Unaipon's application of boomerang principles in designing early helicopters. Learning Outcomes:

- ATSI History & Culture: Understanding the significance of boomerang design and its application in modern engineering.
- Science & Technology: Relating historical and cultural knowledge to contemporary engineering problems.

LEARNING AREAS AND CONTENT

Learning Area	Content
English	Writing and following procedural texts for constructing and modifying wind turbines.
Science & Technology	Principles of fair testing to measure electricity production. Coding a microcontroller to display electricity generation. Engineering challenges such as material jointing and optimizing turbine blade shapes.
Aboriginal and Torres Strait Islander History & Culture	The design of boomerangs and their influence on the shape of airfoils and modern engineering concepts.

The unit was designed to be hands-on, collaborative, and culturally relevant, engaging students in a variety of activities that spanned multiple disciplines. By constructing wind turbines, coding microcontrollers, modifying blade designs, and learning about cultural and historical contexts, students gained a comprehensive understanding of renewable energy principles and engineering concepts while enhancing their procedural writing skills and appreciating the contributions of Aboriginal culture to science and technology.

TOOLS AND RESOURCES REQUIRED

Materials

- Micro:bit, batteries, connecting leads
- Hot glue guns
- PVA glue
- Scissors
- Small hobby DC motor
- Support stands for the motor
- Paddlepop sticks
- Cardboard centre rolls of paper towelling
- Fan, placed 1m away from the turbine being tested
- Web browser access to the makecode.microbit.org development site

Further Reading

A video showing the unit and teacher reactions is available at: https://www.australiancurriculum.edu.au/resources/stem/illustrations-of-practice/drummond-memorial-public-school-years-3-and-4/

REFLECTIONS AND LESSONS LEARNT

This case primarily focused on school students' interdisciplinary learning but simultaneously, it provided authentic opportunities for the development of expertise for interdisciplinary teaching across the school.

MACRO LEVEL

- *School leadership and support.* School principal had a clear vision and enabled teachers to work together by placing this project into the school's plan and using it as an exemplar for all teachers to show that similar teaching activities are valued in the school.
- *Thematic learning.* School teachers used a shared approach of thematic learning that centres around "the book of the term" and worked together carefully crafting each activity to integrate multiple learning areas. The book of the term created a launchpad for co-constructing a cohesive educational experience.

MESO LEVEL

- *Effective collaboration.* Students had the autonomy to choose their partners and self-organised within groups effectively. This allowed them to leverage individual strengths, such as coding or building skills, fostering a powerful collaborative environment where students learned from each other.
- *Hands-on engineering learning.* The practical application of engineering principles was particularly enlightening for students. Issues like the impact of excess hot glue on turbine rotation and the importance of precise blade support placement prompted spontaneous lessons in engineering concepts, including the use of tools like a drill press under supervision.

- *Exploration of materials.* The exploration of different adhesives like PVA glue, prompted by student preference for less messy alternatives to hot glue, encouraged creativity and problem-solving. This flexibility allowed students to personalize their approach to construction, enhancing their ownership of the project.

MICRO LEVEL

- *High student engagement.* The most notable outcome was the high level of engagement among students throughout the project. Despite initial concerns about the complexity of the devices, students quickly accepted the challenge of connecting and coding the micro:bit with minimal assistance. This demonstrated their enthusiasm and readiness to engage with STEM concepts.
- *Abstract conceptual connections.* While the reference to David Unaipon's work and the connection between boomerang wings and turbine blades sparked interest, many students did not fully grasp this abstract connection. Future iterations of the project could include more explicit explanations or demonstrations to enhance understanding.
- *Cultural integration.* Challenges Integrating cultural and historical contexts effectively, such as the Aboriginal contributions to aerodynamics, presented some challenges in making these connections accessible to all students. More targeted instructional strategies could be explored to deepen cultural relevance without increasing complexity.
- *Teachers' flexibility and learning.* Teachers needed to learn to be flexible and respond to students' ideas and needs to learn new knowledge and skills as the project unfolded. The encountered pedagogical challenges served as a stimulus for the improvement of activities and professional learning.

DESIGN PRINCIPLES

The figure below highlights five design principles for teachers' interdisciplinary learning that are most prominent in this case.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

ACTIVITY QUESTIONS

1. How are the highlighted five design principles enacted in this case?

2. Which other design principles are also featured in this case, and how?

3. What additional design features, not covered by the principles, are critical in this case?

4. In what ways can the ideas from this case be adapted to enhance teachers' interdisciplinary learning in your own context?

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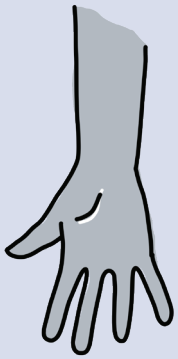
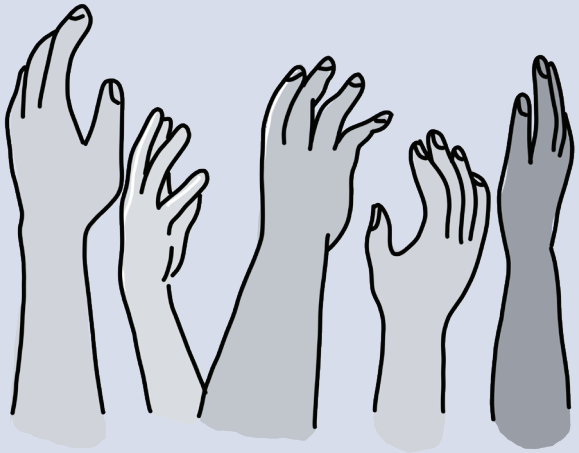


LEARNING BY DESIGN FOR PLAYFUL LEARNING OF INTERDISCIPLINARY TOPICS



PRE-SERVICE TEACHERS' PROFESSIONAL INTERDISCIPLINARY LEARNING

PETER REIMANN
THE UNIVERSITY OF SYDNEY

CONTEXT

The context of this interdisciplinary professional learning project is a 5 week long course for Secondary Education students in their last year of university. The students have to take this course to develop their understanding of the use of information communication technology (ICT) in the classroom. It's a 2 credit points course.

The course is 'hands-on' with only two lectures and 5 tutorials of 2 hours each, plus independent study. The course is convened by a lecturer and involves one or two tutors. In the tutorials, students work in teams of typically 3 students.

While not primarily designed for teaching for developing interdisciplinarity expertise in pre-service teachers, the course offers opportunities for interdisciplinary learning in two forms. Firstly, the guiding vision of teachers as designers promotes the idea that pre-service teachers should design for interdisciplinary learning of (future) students and make interdisciplinary research accessible to them. Secondly, pre-service teachers work on topics from researchers who are engaged in interdisciplinary research. In our case, that is the Charles Perkins Centre at the University of Sydney, which conducts interdisciplinary health sciences research.

AIMS AND PURPOSE

The unit of study focuses on playful learning, scenario-based learning from and with multimedia and Technological Pedagogical Content Knowledge (TPACK) as its underlying conceptual frameworks. Pre-service teachers are provided with an overview of the principles for designing playful multimedia resources to enhance the learning process. The unit of study aims to offer hands-on experience in designing, developing and producing a learner-centred digital resource on an interdisciplinary topic.

CAPABILITIES

The general capabilities that pre-service teachers develop are (NESA 2014/2018):

2.6.1 Information and Communication Technology (ICT)
Implement teaching strategies for using ICT to expand curriculum learning opportunities for students.

3.4.1 Select and use resources
Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning.

4.5.1 Use ICT safely, responsibly and ethically
Demonstrate an understanding of the relevant issues and the strategies available to support the safe, responsible and ethical use of ICT in learning and teaching.

6.3.1 Engage with colleagues and improve practice
Seek and apply constructive feedback from supervisors and teachers [tutors and peers] to improve teaching practices.

Specific learning outcomes are:

- A basic understanding of and some practice with a teacher-oriented design method
- Playful learning with game-elements, specifically scenario-based learning experiences
- Designing for various learner needs
- Understanding interdisciplinary research by creating learning resources from authentic research papers.
- Skills in using presentation software for non-linear, branching scenarios

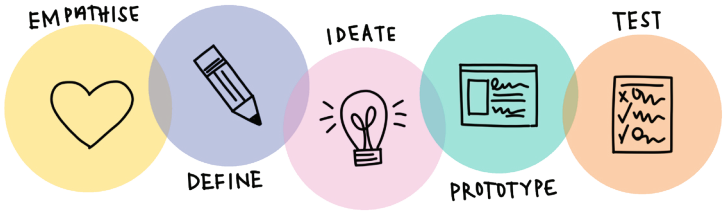
APPROACH

This course was informed by two fundamental ideas: teachers as designers and project-based learning.

- **Teachers as designers; learning by designing**
  This approach views teachers not just as facilitators or knowledge providers, but as designers of learning experiences. They actively design and shape the curriculum, classroom activities, and educational environments to foster engagement and deep understanding.
- **Project-based learning**
  PBL is an instructional approach where learners engage in real-world projects that require them to investigate and respond to complex questions or problems. It emphasises active learning through exploration and creation.

KEY CONCEPTS

DESIGN THINKING



Design thinking is a problem-solving approach that emphasises empathy, creativity, and iterative testing. It involves understanding users' needs, defining problems, ideating solutions, prototyping, and testing to refine ideas and arrive at innovative solutions. This process encourages a deep understanding of the user experience and fosters creative solutions through collaboration and experimentation.

MULTIMEDIA LEARNING THEORY

Multimedia Learning Theory posits that people learn more effectively when they engage with both visual and auditory materials rather than relying on text alone. Developed by Richard Mayer, this theory emphasises that well-designed multimedia presentations—incorporating text, images, audio, and video—can enhance understanding and retention by taking advantage of dual cognitive channels. Key principles include the use of coherent, non-redundant content and segmenting information to reduce cognitive overload, thus facilitating more effective learning.

PLAYFUL LEARNING

Playful Learning is an educational approach that integrates play into the learning process, leveraging the natural curiosity and creativity of children. It emphasises exploration, experimentation, and discovery through activities that are enjoyable and engaging. By incorporating elements of play, this approach aims to foster a love of learning, enhance problem-solving skills, and support social and emotional development. Playful learning encourages active participation and helps students build a deeper understanding of concepts in a fun and motivating environment.

SCENARIO-BASED LEARNING

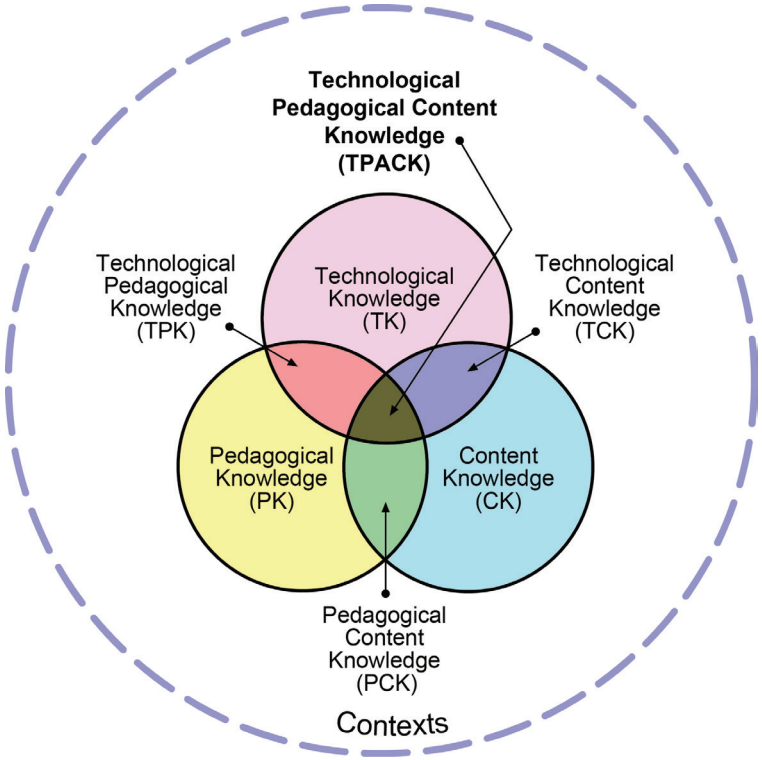
Scenario-Based Learning is an instructional method where learners engage with realistic scenarios to apply their knowledge and problem-solving skills. In this approach, learners are presented with detailed, context-rich situations that mimic real-world challenges or decisions, allowing them to explore and practice their skills in a controlled environment. This method promotes critical thinking, decision-making, and the ability to adapt to complex situations by immersing learners in dynamic, interactive experiences that mirror actual tasks or problems they may face.

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

TPACK (Technological Pedagogical Content Knowledge) is a framework that integrates three key forms of knowledge necessary for effective teaching with technology:

Content Knowledge (CK): Understanding the subject matter being taught
Pedagogical Knowledge (PK): Knowledge of teaching methods and strategies.
Technological Knowledge (TK): Proficiency with technology and its application in the classroom.

TPACK emphasizes the intersection of these three domains, suggesting that effective teaching with technology requires an understanding of how technology can be used to support content knowledge and pedagogical strategies. The framework helps educators design and implement technology-enhanced learning experiences that are pedagogically sound and content-specific.



DESIGN AND IMPLEMENTATION

Design Task: Pre-service teachers create, with Google Slides, a design--a plan and prototype–of a stand-alone digital resource that engages students with specific learning needs in playful learning.

- Stand-alone means that the resource needs to function without the teacher being involved.
- Specific learning needs refer to the needs of students who do not engage well with the classroom teaching strategies that the teacher has to offer.
- Playful learning means that the learning resource comprises a combination of
  - Game mechanics
  - Aesthetic visual design
  - Narrative design
  - Audio design
  - Incentive system
  - Focus on learning standards

When creating their design of an interdisciplinary resource, pre-service teachers are suggested to follow a design thinking process that broadly covers four steps.

DESIGN STEP 1: EMPATHISE, PERSONA CREATION

Pre-service teachers begin by understanding the needs and experiences of their target audience. They create detailed personas (Figure 1) that represent different types of students who will use the resource. This involves gathering insights into their learning preferences, challenges, and interests to ensure the resource addresses their needs effectively.

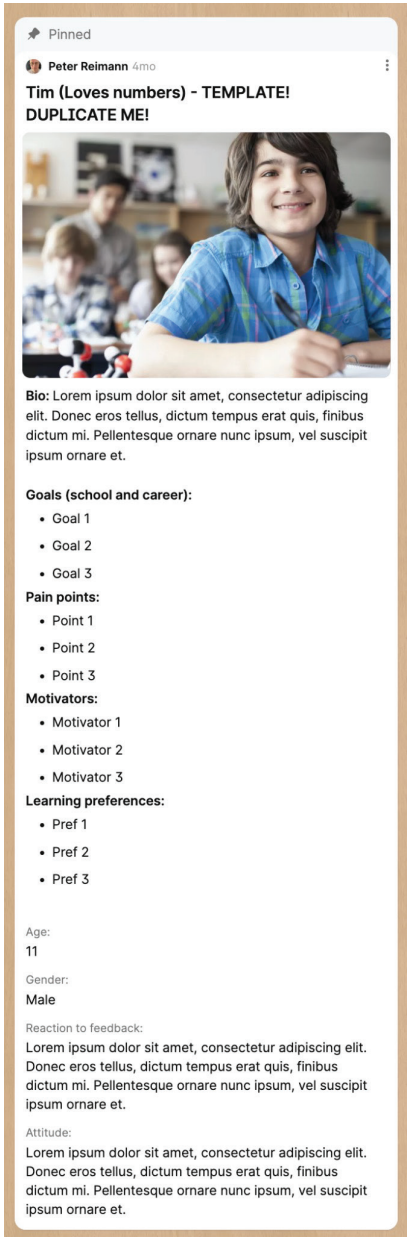


Figure 1. Example of a persona

DESIGN STEP 2: IDEATE

Pre-service teachers brainstorm a wide range of ideas for integrating interdisciplinary concepts into the resource. They encourage creativity and explore different methods and tools that could enhance learning. The focus is on evaluating and selecting the most promising ideas based on feasibility and alignment with the personas' needs.

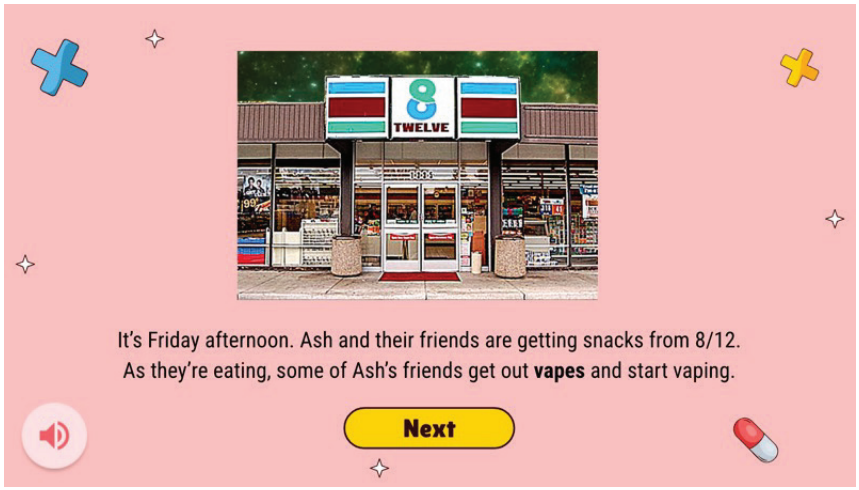


Figure 2. Example of google slide

DESIGN STEP 3: DESIGN AND PROTOTYPE

Pre-service teachers develop initial versions of the resource using Google Slides (Figure 2), incorporating selected ideas and interdisciplinary elements. They create a prototype that includes key features and content, ensuring it aligns with the personas' needs and the overall learning objectives (Figure 3). This prototype serves as a tangible representation of their ideas.

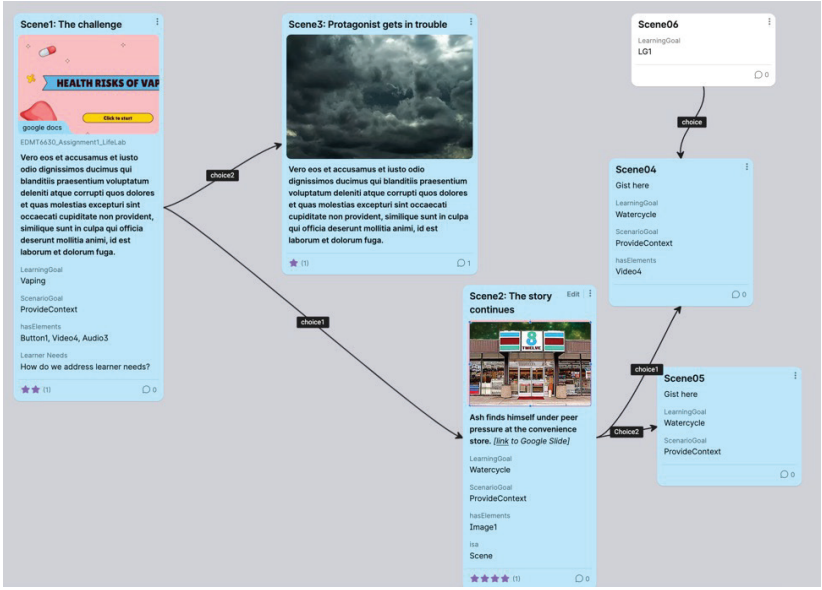


Figure 3. Example of a padlet layout

A **Padlet** is a digital tool that functions as a virtual bulletin board, allowing users to post content such as text, images, videos, and links in a collaborative online space.

STEP 4: TEST AND IMPROVE

The main technique to test is the think-aloud method. Think aloud is method frequently used to test user interfaces (in design) and is also a research method in (problem-solving) psychology. The basic instructions can be very simple: "Tell me what you are thinking about as you work." People can respond easily to this, especially if the experimenter gives a few categories of thoughts as examples: things they find confusing decisions they are making, and the like. Pre-service teachers are given the instructions in Figure 4.

A GUIDE FOR TESTING THE DESIGN

- Prepare in your group to welcome a visitor from another group who will interact with your scenario slides as a learner.
  - Get the scenario ready.
  - Make sure you know how to elicit data from the visitor with the thinking-aloud protocol.
- One of you welcomes the visitor and conducts the thinking-aloud activity. The others take notes.
- After the visitor has worked through the scenario, you may want to ask the visitor some clarification questions regarding their experience of your scenario.
- Say thank you to the visitor and send them back to their group.
- Discuss in your group your main insights.

Figure 4. Think-aloud instructions

TOOLS AND RESOURCES REQUIRED

Classroom:
The learning environment consists of conventional seminar rooms (with projection technology).

Online resources
A Canvas web site and resources in the form of Google Docs.

ASSESSMENT GUIDELINES

Pre-service teachers complete the following assessment task that includes two components.

THE ARTEFACT

This assignment will be marked Pass/Fail. To get a Pass, the work needs to meet all of seven criteria:

1. The content is factually correct, including its interdisciplinary aspects.
2. The learning resource is in parts interactive and contains elements that present students with challenges, choices and consequences of choices.
3. The sequence in which the learning content is made accessible follows a coherent logic.
4. The design of the individual slides/screens is consistent.
5. The text parts are easy to read, written in a conversational style and free of spelling or grammatical mistakes.
6. One or more images are included with more than a decorative function.
7. One or more sound/voice/video elements are included with more than an entertaining function research team.

INDIVIDUAL REFLECTION

Pre-service teachers are given the following task:

- Reflect on the development of your competence to use ICT for playful learning, including your design knowledge
- Review your weekly reflections, analyse what you have learnt from the experience and how you might transfer any of the knowledge, skills or understandings from any of the big ideas in this unit to your classroom.
- As part of this, you should provide evidence of the evolution of your knowledge (e.g. notes, design decisions, learning content developed). These can be included as appendices but need to be cited and/or referenced in your reflective statement.
- How you have demonstrated knowledge and understanding of GTS specific to ICT:
  - 2.6.1 Information and Communication Technology (ICT)
    - Implement teaching strategies for using ICT to expand curriculum learning opportunities for students.
  - 3.4.1 Select and use resources
    - Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning.
  - 4.5.1 Use ICT safely, responsibly and ethically
    - Demonstrate an understanding of the relevant issues and the strategies available to support the safe, responsible and ethical use of ICT in learning and teaching.
  - 6.3.1 Engage with colleagues and improve practice
    - Seek and apply constructive feedback from supervisors and teachers [tutors and peers] to improve teaching practices.

Think about the following when writing your personal reflections:

- Design thinking (as a whole process or the individual aspects of the process that specifically piqued your interest) what surprised you about the process? What critical incidents (e.g. ‘aha’ or ‘oops’ moments during the process, or incidents that became critical / important in the design of your scenario-based learning when reflecting back)
- Playful learning and personalised instruction
- Integration of multimedia
- Ethical use of AI in education
- Teamwork

REFLECTIONS AND LESSONS LEARNT

MACRO LEVEL

- *Curriculum integration.* Interdisciplinary learning tasks were integrated into the existing course module, focused on developing pre-service teachers' ICT skills. Therefore, the project tasks were designed to fit the existing curriculum topics and purposes, but they also provided enough space for teachers' interdisciplinary learning.
- *Local infrastructure for interdisciplinary learning.* The course drew on the unique local possibilities for pre-service teachers to engage with topics from researchers who do interdisciplinary research within the university. This enabled them to expand and deepen pre-service teachers' engagement with and understanding of interdisciplinary research practices within their own university. However, in the absence of such possibilities, a similar course could be conducted by engaging pre-service teachers with any, interesting for them, interdisciplinary research papers and topics.

MESO LEVEL

- *Designing for deep engagement with science.* One of the hardest aspects is to support, motivate and enable deep pre-service teachers' engagement with the underlying science within a short course. This aspect potentially could be enhanced by more guidance and scaffolds, such as offering a structured introduction to interdisciplinary research by specific interdisciplinary researchers, requiring the use of specific high-quality science sources early on and providing a small high-quality pool of such science sources, articulating the task of presenting research ideas interactively in sufficient detail and with examples and offering templates that help to do this. In a longer course, it could be particularly useful to create possibilities for pre-service researchers to meet the interdisciplinary researchers, be in their labs and workplaces and engage in other situated, embodied interdisciplinary learning experiences.
- *Focusing on skills and pedagogies for interdisciplinary learning.* One of the main focuses of the course was to create opportunities for pre-service teachers to gain a basic understanding of and some practice with design thinking, as well as learn to design for playful, scenario-based learning. These design and pedagogical ideas are highly relevant for interdisciplinary teaching. However, their repertoire could be further expanded to include approaches of scenario-based decision-making, scenario-based data inquiry, and others that are highly relevant to interdisciplinary learning and teaching contexts.

MICRO LEVEL

- *Developing 'know-how' for hybrid teaching.* By engaging with pedagogical concepts, design frameworks, and technological tools, pre-service teachers had the possibility to develop their TPACK and gain the initial 'know-how' necessary for embracing hybrid learning. This aspect of teachers' interdisciplinary practices was most explicitly addressed in the course.
- *Diverse pre-service teachers' interests.* It is important to find opportunities to cater to different interests and disciplinary perspectives. For example, our experience showed that English pre-service teachers have a passion for looking at the health science area through the lens of media and communication studies: youth culture, advertisement, social media, etc. However, we did not cater to this perspective sufficiently, and not all secondary pre-service teachers were equally engaged. One of the possible remedies in the future is to provide scenario ideas around the diverse roles that pre-service teachers can take in this task, such as journalists, influencers, etc.

- *Pre-service teachers' dispositions.* Many prservice teachers come to the course with the expectation to have to design 'lesson plans'—in their teaching area only (!)—that include some elements of digital technology. It took us some time to change this disposition, which left little time for productive engagement with the task and learning. One of the possible remedies is to scaffold pre-service teachers' understanding that teaching as design goes beyond lesson planning by stating this early in the course and reminding them that they are asked to create a technology-based learning activity, not a lesson plan or a plan for project-based learning; showing examples of created artefacts that meet and do not meet this expectation; and making connections between new ideas and what pre-service teachers already know (e.g. explaining similarities between scenario-based learning, narratives and

DESIGN PRINCIPLES

The figure below highlights five design principles for teachers' interdisciplinary learning that are most prominent in this case.

ASPECT / LAYER	EPISTEMIC	MATERIAL	SOCIAL	AFFECTIVE
MACRO	COMMUNITIES OF PRACTICE	INSTITUTIONAL SUPPORT	LEADERSHIP	COLLABORATIVE CULTURE
MESO	CONNECTING	LESSON CO-PLANNING	GLOSSARY	MENTORS
MICRO	DISPOSITIONS	TIME	ETHICS	EMPATHY

ACTIVITY QUESTIONS

1. How are the highlighted five design principles enacted in this case?

2. Which other design principles are also featured in this case, and how?

3. What additional design features, not covered by the principles, are critical in this case?

4. In what ways can the ideas from this case be adapted to enhance teachers' interdisciplinary learning in your own context?

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