Empowering Physical Sciences Teachers to Introduce a STEAM Approach: A Path to Active Teaching and Critical Learning

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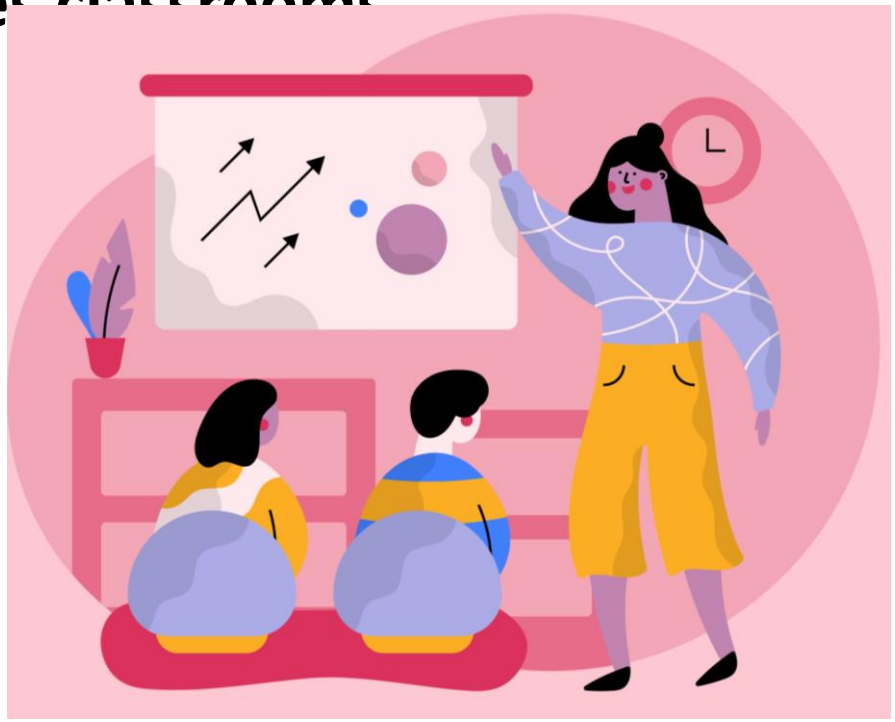
Background: Physical Sciences teaching

Reality in most Physical Sciences classrooms



- Many Physical Sciences teachers use predominantly transmission mode teaching methods
- Tend to adhere to Gibbon's Mode 1 knowledge production:
  - Traditional discipline-based knowledge (cognitive domain)
  - There is usually no connection to the real-world experiences of learners
  - Leading to a neglect of the affective domain

Background: Physical Sciences teaching

(Reality in most Physical Sciences cont.)

Practical work (addressing the psychomotor domain) focus on aspects of the NOS

Science is

- Empirical,
- Tentative
- Theory-driven
- Creativity
- subjective
- Social dimension of science
- Social and cultural embeddedness of science

Current focus in most science classrooms

Tenets usually not attended to in school science classrooms

NOS (Abd-El-Khalick, Bell and Lederman (1998) Recognise the empirical nature of science, but also creative, SUBJECTIVE AND SOCIALLY AND CULTURALLY constructed

Therefore a need FOR

- Gibbon's mode 2 knowledge production
- Epistemological diversity in STEM

TO

Critical Learning to identify pseudoscience and enhance scientific literacy (skills 4IR)

Background: Physical Sciences teaching (cont.)

What should it be?

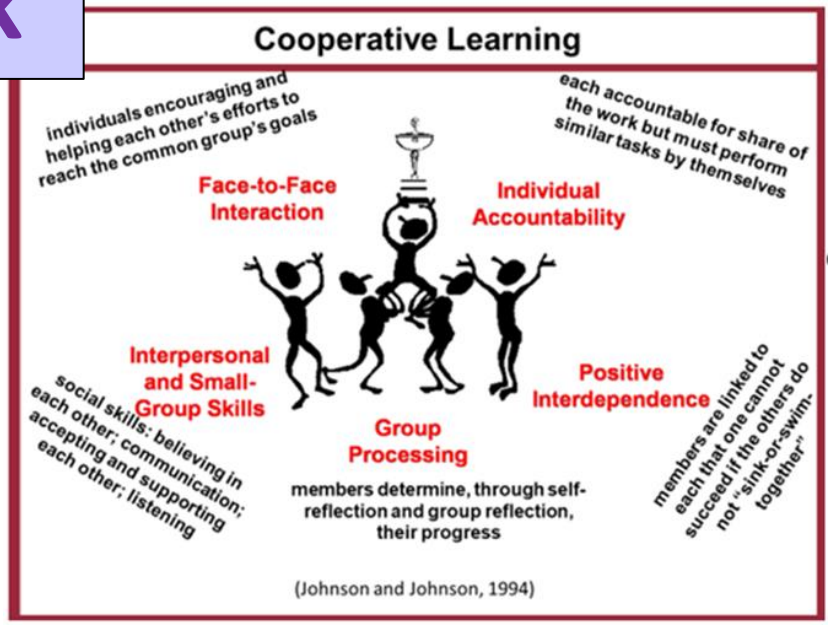
- Gibbon's mode 2 knowledge should be emphasized
  - contextualized science, e.g. Problem-based and interdisciplinary knowledge; STEAM
  - Experience of learners should be included
  - Address the affective domain as well
  - Learner-centered approaches
  - **Develop 21st century skills for their job market**
- Importance of active teaching and critical learning in Physical Sciences
- Challenges in traditional teacher-centred approaches

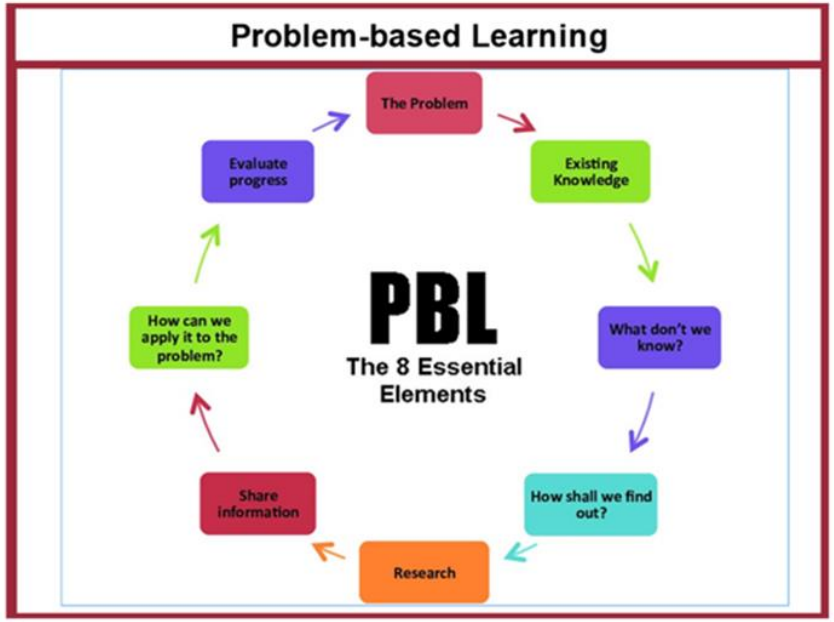
Research Question

How does empowering Physical Sciences teachers using a STEAM approach foster active teaching and critical learning?

Conceptual Framework

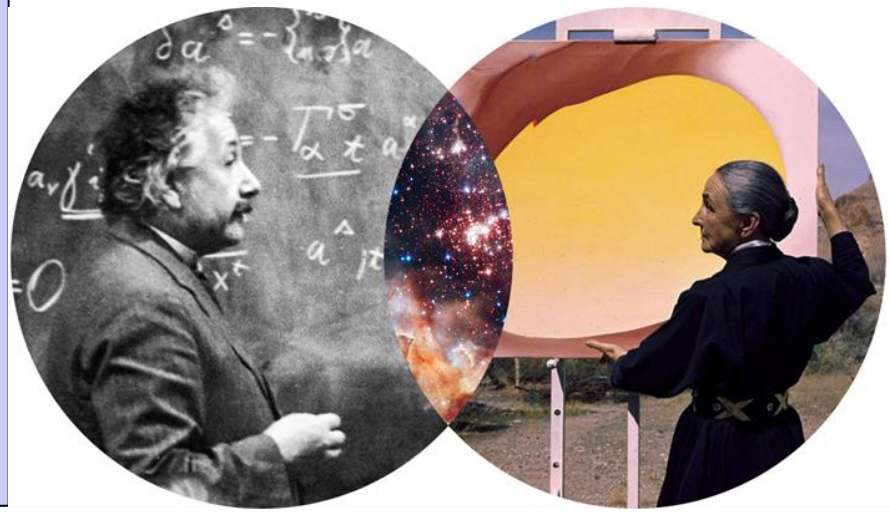
- SDL
  - Taking ownership of learning with or without the help of others (Knowles, 1975)
- Strategy:
  - cooperative and problem-based
  - puppetry
  - STEM – STEAM
    - Shared tenets of arts and science
    - Science-Arts epistemological border crossing
- Affordances for Teachers Professional Development





Science-Arts epistemological border crossing

Shared tenets of Science and Arts



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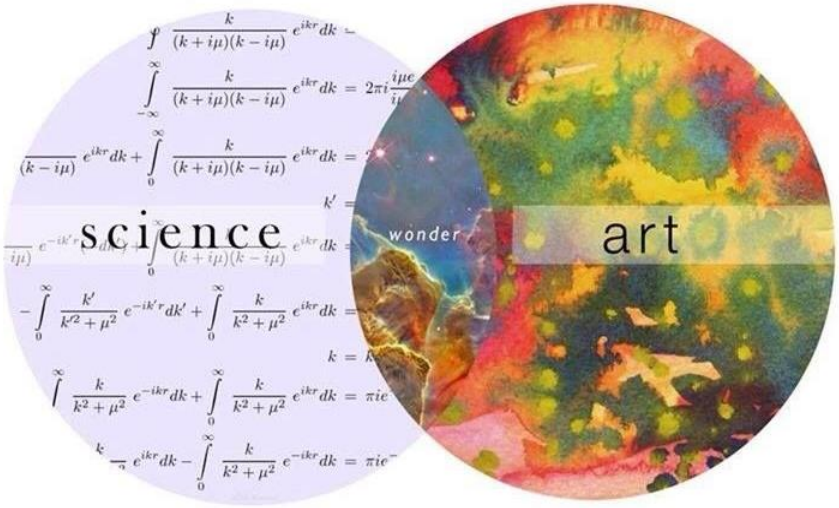

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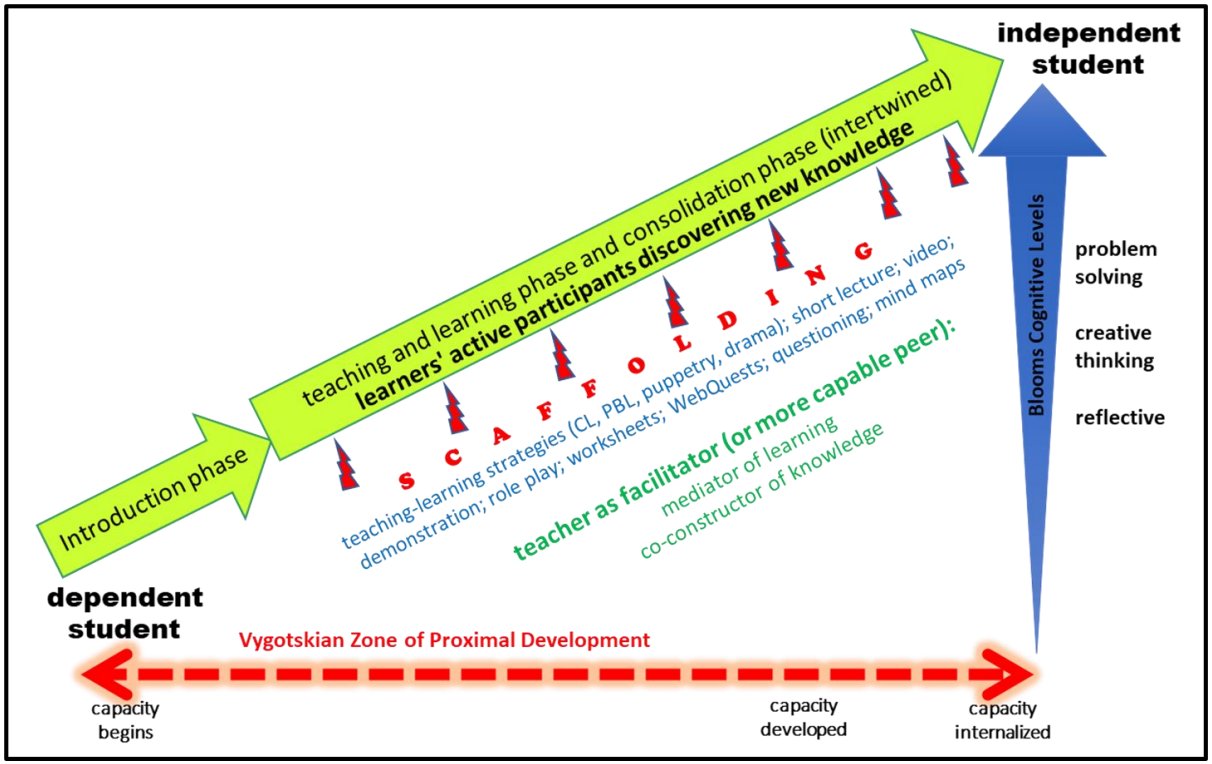
Shared tenets of Science and Arts

Shared tenets	In the Sciences…	In the Arts…
Noticing: Learners notice the world around them	this means **collecting data, whether through informal or formal means**, is essential **for gaining insights** into the functioning of the world	the process involves **closely studying and analysing behaviours** and phenomena in order **to accurately depict and portray** them through artistic mediums.
Wondering: Learners wonder how the world works	scientists engage in the process of **questioning, investigating ideas, and fostering inquisitiveness and hypothesis formation**	By utilising their artistic skills, **artists creatively construct situations, envision stories, and produce mental visuals.**
Visualising: learners visualise ideas to make meaning	**scientists employ various methods** such as designing experiments or developing models **to explore** optimal solutions for problems	artists **transform abstract concepts into tangible forms** through their visual and performed compositions.
Exploring: learners seek to unravel the intricacies of why things exist as they do or to envision alternative realities	scientists **conduct experiments** to explore their world	artists **develop their skills and refine their ideas**, striving to achieve the desired expression.
Communicating: learners must communicate what they understand	Scientists **construct explanations and arguments** with each other, all of which are rooted in evidence.	An **exhibition or performance** often encourages critical feedback from spectators..

Source: Fulton and Simpson-Steele (2016:3-6).

THEORETICAL FRAMEWORK

- Social Constructivism: Learning as a social process
- Zone of Proximal Development (ZPD)



- Scaffolding: Support provided to bridge the ZPD
- The Zone of Proximal Teacher Development (ZPTD)

The Intervention- Day 1

- The **Short Learning Programme (SLP)**, grounded in Self-Directed Learning (SDL) principles
  - Spanned over three days
  - Exploring teachers' abilities and integrating arts into science teaching.
- **Day 1 Focus: Theoretical foundations of STEAM pedagogy**
  - through interactive, cooperative and problem-based learning
  - Researcher-led **micro-teaching session** to model SDL and professional practice
  - Teachers engaged in **individual and group activities** using:
    - **Cross-cultural artefacts**: jigsaw method, puppets, drama-based scenarios, and De Bono's Hats
  - **Aim**: Foster critical discussion, reflection, and application of arts in science teaching

The Intervention- Day 2

Focus: Applying STEAM pedagogy in science teaching.

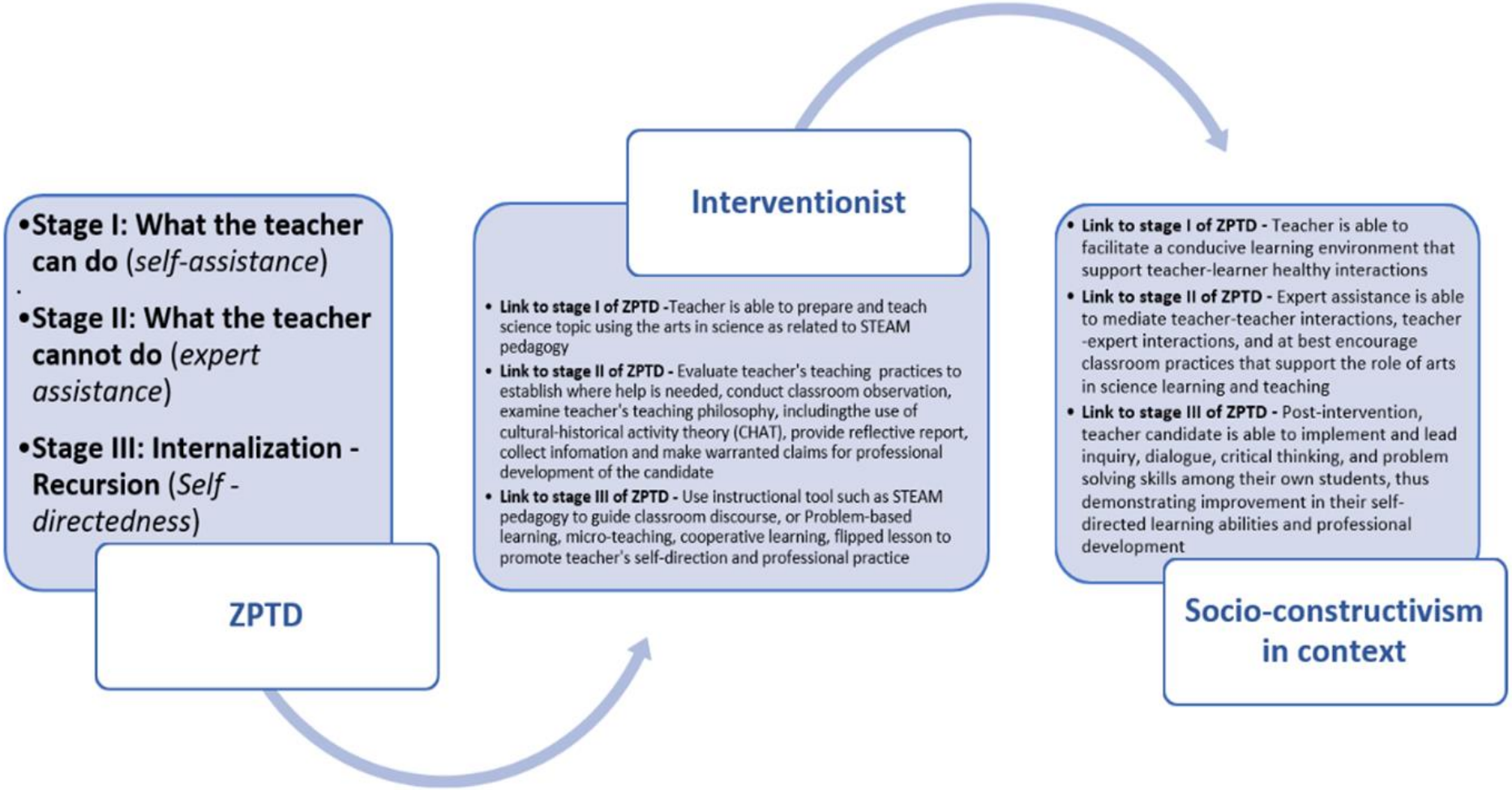
- Teachers designed a **concise STEAM teaching-learning experience without external assistance**
- They delivered **10-minute micro-lessons** in small groups, demonstrating **knowledge transfer from Day 1**
- Researcher **facilitated within the ZPD**,
  - offering scaffolding and
  - constructive feedback
- **Key objective: Identify own professional development needs (SDL)** through critical reflection of their own shortcomings

The Intervention- Day 3

Focus: Addressing gaps identified in previous sessions, reinforcing SDL and professional growth.

- Teachers revisited and refined **STEAM-based learning activities** to strengthen their practice
- The researcher facilitated deeper engagement with **art tools** used on Day 2
- Teachers developed **individual STEAM teaching-learning experiences** on topics of their choice
- Self-assessment: Identified **personal learning goals and development needs**
- **Three-month follow-up:** Classroom observations to assess **knowledge transfer and impact**

Interplay between Theoretical and Conceptual Frameworks



Diagrammatic representation of ZPDT

Source: Mafokwane (2024) Adapted and modified after Warford (2011)

Methodology

- Research Design: Mixed-methods (QUAL:quan)
- Interpretivist paradigm
- Participants: 15 Physical Sciences teachers from Mopani District, Limpopo, South Africa
- Five participate in the observations and interviews
- Data Collection: Observations (RTOP) & interviews
- Ethical considerations

Key Findings – **Observations (RTOP)**

Components of RTOP	***RTOP Questions***	**Average and Mean Score**	**Teacher performance**				
			ST1	**ST3**	**ST7**	**ST10**	**ST14**
Design and implementation of STEAM pedagogy	Q1 – Q5	Average	11	16	14	15	17
		Mean	2,2	3,2	2,8	3	**3,4**
Content (propositional knowledge)	Q6 – Q10	Average	17	14	14	15	16
		Mean	**3,4**	2,8	2,8	3	3,2
Content (procedural knowledge)	Q11 – Q15	Average	8	12	15	13	14
		Mean	1,6	2,4	3	2,6	**2,8**
Classroom culture (communicative interactions)	Q16 – Q20	Average	14	12	13	12	14
		Mean	**2,8**	2,4	2,6	2,4	**2,8**
Classroom culture (student-teacher relationships)	Q21 – Q25	Average	13	13	13	13	14
		Mean	2,6	2,6	2,6	2,6	**2,8**
Overall teacher performance by Mean score			**2,52**	**2,68**	**2,76**	**2,72**	**3**

Key Findings – **Observations (RTOP)**

	Teacher performance				
	ST1	**ST3**	**ST7**	**ST10**	**ST14**
Overall teacher performance by Mean	**2,52**	**2,68**	**2,76**	**2,72**	**3,0**

- ST14 received the highest mean score of **3,0**
  - holds a BSc degree and a PGCE, may possess strong content knowledge
  - have had greater exposure to the subject matter
  - employed arts integration:
    - he used **visual representation** of acid and bases compounds
    - and incorporated daily items such as toothpaste, soap, and perfumed
    - create a more engaging and interactive classroom (49 lle) environment
    - learners develop a deeper appreciation for science and the arts.

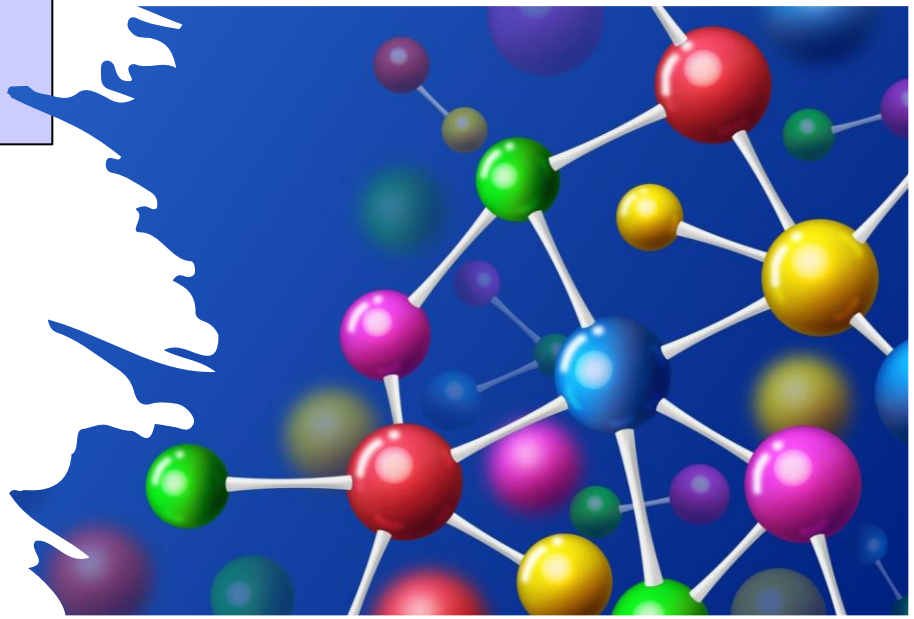
Key Findings – **Observations (RTOP)**

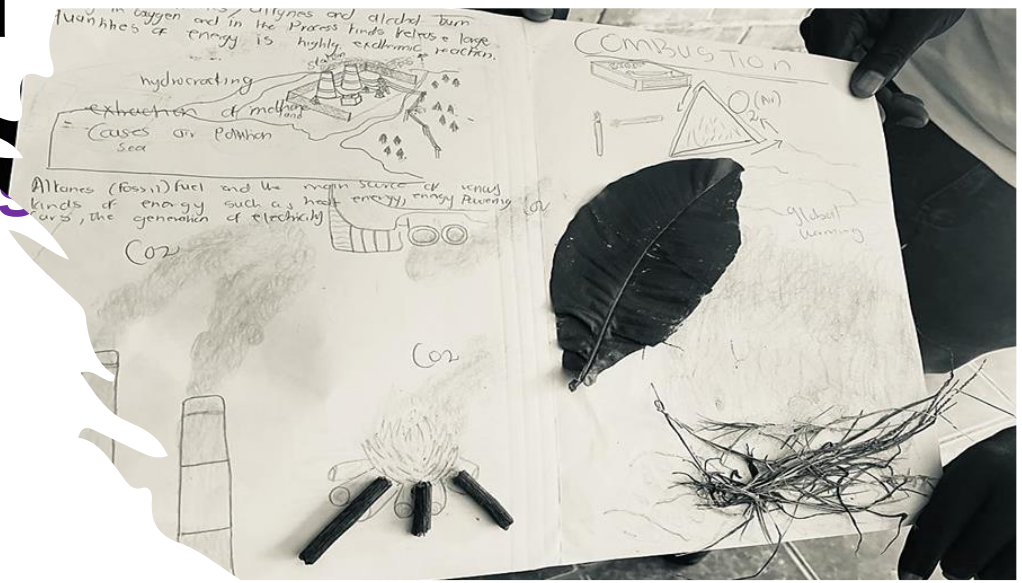
	Teacher performance				
	ST1	**ST3**	**ST7**	**ST10**	**ST14**
Overall teacher performance by Mean score	**2,52**	**2,68**	**2,76**	**2,72**	**3,0**

- ST1 received the lowest mean score of **2.52**,
  - beginner science teacher with only two years of teaching experience.
  - limited experience may have affected his ability to effectively engage students and facilitate reflective learning (Zimmerman, 2016).
- employed arts integration:
  - used **images** of falling objects, phases of the moon, and the circular rotation of the earth to
  - illustrate key concepts related to **learners' social context**
  - learners to **dramatise** pushing forces, including using arts **drawings**

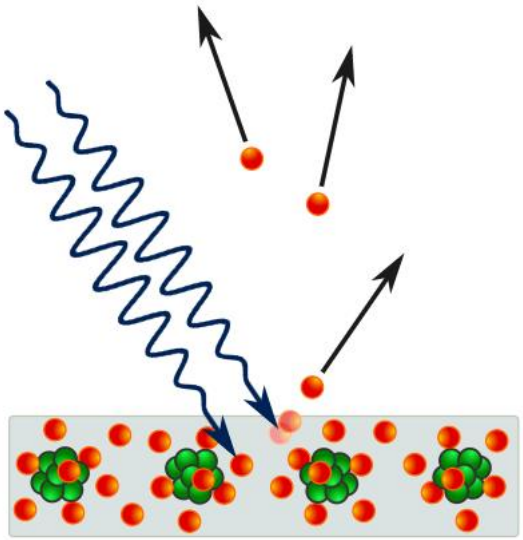
Key Findings – **Observations (RTOP)**

- ST3 used **visual aids** such as **drawings**, diagrams, and charts to explain complex chemical ideas related to organic molecules **and their applications to everyday life**

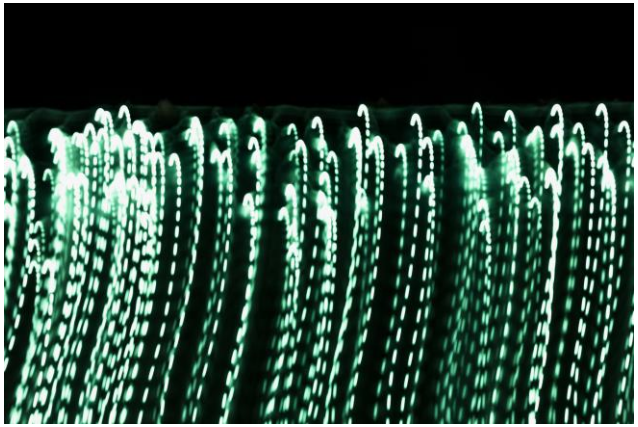




Key Findings – **Observations (RTOP)**



- ST7 used **drama** to illustrate the concept of photoelectric effects:
  - The learners took turns in the **roleplay** to demonstrate how a metal with sufficient kinetic energy ejects electrons from a metal surface
  - The teacher **dramatised** by **roleplaying** herself as a Lightwave and her learners as energy source.



Key Findings – **Interviews**

Teachers' views of STEAM pedagogy

n	Items (Interview Questions	Quotes from Participating Physical Sciences Teachers	Freq	Sub-total	Teacher ID
1	What do you think STEAM pedagogy is?	Integration of arts in teaching STEM	///	3	ST14, ST7, ST3
		Apply arts in STEM subjects	//	2	ST10, ST1
2	Do you think integrating art into your science lessons and/or classroom is something you should consider in the future? If yes, why? If no, why not?	**Yes, fosters creativity, inquiry and process skills**	////	4	ST14, ST7, ST3, ST10
		Sometimes, not easy to include in all my lessons	/	1	ST1
3	In terms of classroom culture and creating a conducive learning environment, how would you improve your learners' reflective thinking and reasoning skills?	Use of dramas, learners as a source, and contextualisation	//	2	ST10, ST3
		Use visual representations and homemade artefacts	///	3	ST14, ST1, ST7

Key Findings – Interviews

Teachers' views of STEAM pedagogy

n	Items (Interview Questions	Quotes from Participating Physical Sciences Teachers	Freq	Sub-total	Teacher ID
4	What do you think of STEAM pedagogy as a tool for integrating the arts into STEM lessons?	**It can make learning more engaging and enjoyable for students.**	///	3	ST14, ST7, ST3
		No, it won't make any difference	//	2	ST10, ST1
5	How did your learners respond to the integration of the arts into the science classroom when you were observed by the researcher?	**Learners were motivated and actively engaged in creative and critical thinking skills.**	///	3	ST14, ST7, ST3
		Time-consuming, some learners hold the same view regarding arts activity in science	//	2	ST10, ST1
	Totals:	**Perspectives on STEAM**		**10**	
		Perspectives on active and critical learning		**10**	
		Possible challenges		**5**	

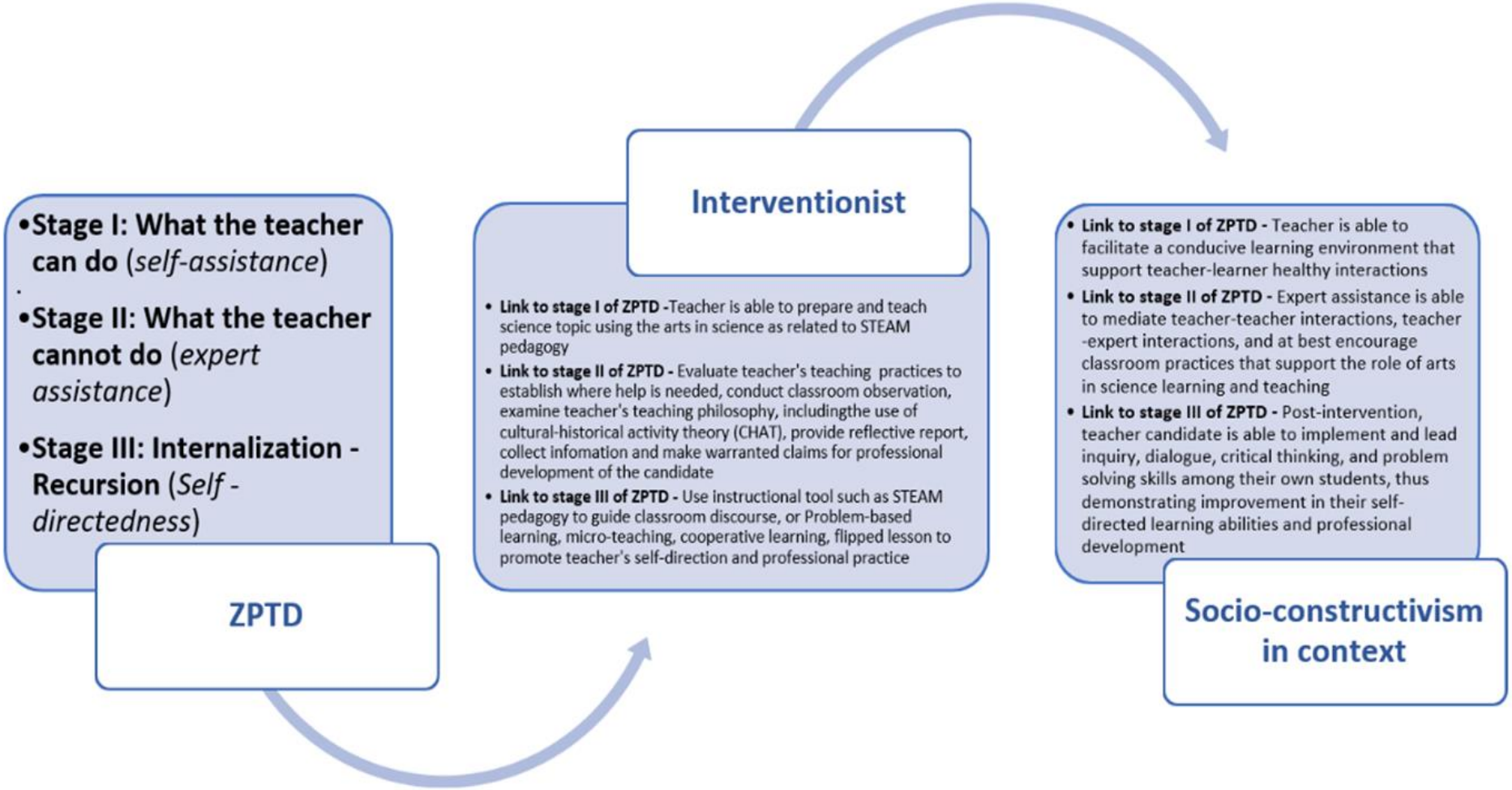
Interviews (Overview)

Teachers' views of STEAM pedagogy	Freq - total	Key Findings
Perspectives on STEAM	10/25	Evidence that PSTs have some understanding of integrating the arts into science, effectively creating a STEAM approach.
Perspectives on active and critical learning	10/25	Arts integration supports creativity, peer collaboration, and enjoyment of science
Possible challenges	5/25	Time consuming Finding resources to support STEAM integration Motivating learners effectively

Did Empowering Physical Sciences Teachers to Introduce a STEAM Approach provided a Path to Active Teaching and Critical Learning?

- **Main finding:**
  - The findings suggest that empowered Physical Sciences teachers integrating STEAM can contribute to active teaching and critical learning
- **Evidence of successes:**
  - Teachers improved engagement strategies using arts-based methods (e.g., drama, visual aids)
  - The SLP enhanced collaboration and communication skills, fostering creativity despite resource constraints
- **What were the limitations?:**
  - Conceptual and resource-related challenges still hinder full STEAM implementation.
  - Time constraints limited teachers' ability to consistently apply arts integration

Interplay between Theoretical and Conceptual Frameworks

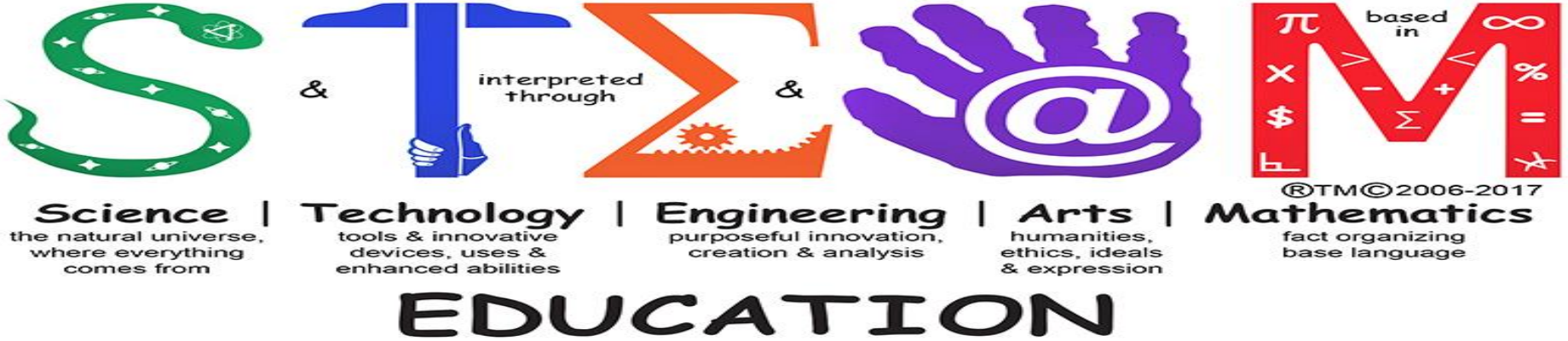


Diagrammatic representation of ZPDT

Source: Mafokwane (2024) Adapted and modified after Warford (2011)

Conclusion & Way Forward

- Need for support structures (mentorship, resources, and continued training).
- Encouraging teacher agency in implementing STEAM.
- Future research: Scaling up STEAM pedagogy in different contexts.



Afrikaans: Baie Dankie

English: Thank you

Setswana: Ke a leboga

Italian: Grazie mille or Molte grazie