Developing teacher competencies for teaching evolution across the primary school curriculum. A design study of a pre-service teacher education module

Additional file 1: Extended Syllabus of Final Module Design

The full syllabus and materials can be accessed on the OpenEvo learning hub of the Max Planck Institute for evolutionary Anthropology:

- German version: https://openevo-learninghub.eva.mpg.de/course/view.php?id=66
- English version: https://openevo-learninghub.eva.mpg.de/course/view.php?id=5 *(accessible by December 2023)*
  (*Please note that the module was originally designed in German, and additional resources such as videos, literature and lesson materials in German language were provided. The English version may therefore not fully represent the content of the original module. Where possible, we replaced the German materials with English equivalents*.)

Overarching materials:

- Database of children's books
- Database of videos for children
- Database of research literature on teaching evolution in primary school
- Collection of teaching materials and resources provided on the learning management system

Module topics and schedule

Week	Topics	Learning Goals	Materials, Tools	Methods, Assignments	Key integrated literature/references (selection)
				Pre-survey regarding attitudes and knowledge about teaching evolution in primary school	In part inspired by Graf (2015)
Unit 1: Introduction and Conceptual Foundations					
1	Introduction; Evolution in primary school; **Evolutionary concepts** and the role of conceptual learning; **Learning progressions** for teaching evolutionary concepts in K-6	Teaching evolution in primary school connects to students' interests and many curriculum goals; Evolution has several meanings; Evolutionary theory is made up of a set of concepts; Evolutionary concepts can and should be taught across the curriculum and grades (Learning progressions)	Presentation; local standards and curricula; results of pre-survey	Small group discussions: What is Evolution ● Mindmap ● Definition of evolution ● Questions regarding evolution/teaching evolution in primary school	GDSU (2013); Graf (2015); Lehrer & Schauble (2012); Russel & McGuigan (2019)
2	**Variation**, (genetic and cultural) **Inheritance**; essentialism, genetic determinism	Students' essentialist thinking can hinder the appreciation of variation within species; Instructional methods can help to overcome essentialist thinking; Children have intuitive understandings about the inheritance of traits; some human traits are inherited culturally/	Presentation; Zoom break-out rooms and shared Google docs	Small group activity and discussion: Collect variation in the group; discuss pedagogical issues; Small group discussion: pedagogical issues with implying all traits are genetically	Bruckermann et al. (2020); Buchan et al. (2020); Campos & Sá-Pinto (2013); Duncan et al. (2017); Emmons & Kelemen (2015); Graf & Schmidt-Salomon (2017); Lehrer & Schauble (2004); McGuigan & Russell

		through social learning		inherited/determined	(2015); Moya et al. (2015); Russell & McGuigan (2015, 2019), Shtulman & Schulz (2008
3	Phylogenetic **trees**/family trees and systematics, common descent; tree thinking	Tree thinking often presents learning difficulties, but they can be overcome through appropriate instructional methods; Family trees, tree branches, construction of mobiles, grouping and sorting of animals by commonalities	Presentation; Tree branches; Zoom break-out rooms, polls, and shared Google docs	Poll/Quiz on tree thinking, Estimation of number of ancestors ca. 20 generations back	Baum (2008); Baum et al. (2005); Campos & Sá-Pinto (2013); Chanet & Lusignan (2009); Jördens et al., (2011); Graf & Schmidt-Salomon (2017); Kuschmierz et al. (2020); McAlexander (2022); O'Hara (1997); Pindactica (2015); Russell & McGuigan (2019); Schmidt-Salomon & Kindler (2015); Tweet & Lewis (2016)
	History of life, **deep time** (thinking); Dinosaurs, Fossils	Deep time thinking often presents learning difficulties due to large numbers and unimaginable time spans, but they can be overcome through appropriate instructional methods; the theme can connect to children's fascination with dinosaurs and fossils	Presentation; Zoom annotation tools; Video: Big Family: A fantastic journey into the past; Moodle forum	Annotation on timeline; Discussion of video Big Family	Beniermann et al. (2021); Graf & Schmidt-Salomon (2017); Greiten & Brennecke (2017); Kuschmierz et al. (2020); Pindactica (2015); Russell & McGuigan (2019); Schmidt-Salomon & Kindler (2015); Solcher (2007); Wieder & Graf (2017)
4	**Function** of traits, **fitness**, **adaptation**, natural	Students often have misconceptions regarding the evolutionary origins of traits, such as teleological, intentionalist,	Presentation; Zoom break-out rooms, polls, and shared Google docs;	Small group discussions: Quiz on natural selection and fitness; discussion of results	Bruckermann et al. (2020); Beniermann et al. (2021); Boston University Child Cognition Lab (2019);

	selection, related learning difficulties and miscon-ceptions; animals and plants as example contexts	transformationist and Lamarckian thinking; instructional methods to teach natural selection include stories, simulation games, and computer simulations	Moodle assignment for sharing of stories	Create a natural selection story and share on Moodle	Brown et al. (2020); Emmons et al. (2016, 2017); Fenner (2013); Kelemen et al. (2014); Kuschmierz et al. (2020); GDSU (2013); Graf & Schmidt-Salomon (2017); Marquardt-Mau & Rojek (2011); Pindactica (2015); Ronfard et al. (2021); Schmidt et al. (2017); Shtulman et al. (2016)
5	**Self-directed exploration:** further mechanisms of evolution				
	Drift, founder effect, bottleneck effect & biodiversity	Evolutionary concepts relate to curriculum themes of biodiversity and help understand the impact of humans on the environment	Reading Text, Teaching material: Simulation game	Self-directed exploration of at least one of the topics on the LMS (Presentation, materials); Possibly document PCK-related reflection in the portfolio	Campos & Sá-Pinto (2013)
	Sexual and **social selection**	Not only the natural but also the social environment presents selection pressures. Social and sexual selection can lead to traits that would otherwise not be adaptive	Presentation; lesson plan on peacocks, Videos about birds of paradise		Graf & Schmidt-Salomon (2017)
	Niche construction	Animal behavior often has a role in evolution; animals are not just passively adapting. Adaptation has two meanings: individual level and population-level	Presentation; example species: beaver; earth worm; emperor penguin		GWV Fulda GmbH (2011); Marquardt-Mau & Rojek (2011); Laland & Chiu (2020)
	Symbiosis and **coevolution**	Evolution is more than competition; Evolution can lead to interdependence between	Presentation; Examples: flowering plants and pollinator		Bar-On et al. (2018); Mennerich (2012)

		species; symbiosis is a relationship that is advantageous for both species; evolutionary concepts relate to curriculum themes of relationships in ecosystems	insects (relation to school garden), humans and domesticated species; and others		
Unit 2: Human Evolution - Application of concepts to our own species, with a focus on traits that connect to curricula, everyday experience, health, and social-emotional competencies					
6	Primates and apes	Humans are primates and we share several traits with other primates/apes; chimpanzees and bonobos are our closest ancestors	Presentation; Zoo visits (e.g. Leipzig Zoo ape enclosure and research center Pongoland)	Discussion: we primates have prehensile hands and feet and finger/two nails - why; we primates have good color vision (red-green contrasts)	Graf & Schmidt-Salomon (2017);
	Hominin fossils, morphological differences between humans and chimpanzees; upright walking, running, throwing, body hair, skin color	To understand when and why morphological differences between humans and our closest relatives evolved, we can explore hominin species; many hominin species probably existed and we only know about a few and there are speculations and uncertainties about how they were related; evolution of human morphology can be related to themes in sports and health as well to learning goals of fostering appreciation of human diversity	Presentation; Hominin fossil skulls; Zoom break-out rooms and shared Google docs	Small group discussion: hypotheses about the causes of morphological differences between humans and chimpanzees; Reflection about traits that allowed *Homo erectus* to survive Reflection about the evolution of lack of body hair and skin color Reflection/prediction about the skin color of polar inuit	Barr et al. (2015); Bramble & Lieberman (2004); Brennecke et al. (2017); Graf & Schmidt-Salomon (2017); Hanisch & Eirdosh (2022a,b); Jablonski (2017); Jablonski & Chaplin (2017); Magona et al. (2018); Roach et al. (2013); Schmidt-Salomon & Kindler (2015)
7	Cooperative hunting / Cooperation	Humans are a cooperative species; Evolution education often emphasizes competition, but cooperation also plays a role	Presentation; Hominin skulls; modified simulation games to represent the	Poll and discussion: What makes us human?/What traits are responsible for the evolutionary success of our	Duguid et al. (2014); Hanisch & Eirdosh (2021); Hanisch & Eirdosh (2022a,b); Hare et al.

		in evolution; There might have been selection for social tolerance in the evolution of our species	evolution of cooperation; Video: Michael Tomasello - What makes us human; Video: Yuval Harari - What explains the rise of humans?	species?	(2007); Koomen & Herrmann (2018a,b); Melis et al. (2006); Obach (2003), Tomasello et al. (2012)
8	**Self-directed exploration**: Themes in human evolution				
	Tool making, social learning, teaching, childhood	Social learning, teaching, an extended childhood and cooperative child care are core traits and social behaviors of our species, enabling the creation of more and more complex tools.	Presentation; Video: Alison Gopnik	Self-directed exploration of at least one of the topics on the LMS (Presentation, materials); Possibly document PCK-related reflection in the portfolio	Gopnik et al. (2000); Herrmann et al. (2007); Hanisch & Eirdosh (2022a,b); Zimmerman & Radespiel (2007)
	Culture/ cumulative culture, cultural evolution	Human culture is different from the culture of other animals by its cumulative nature; Cultural evolution and genetic/biological evolution can be compared by analogical evolutionary processes; the theme of cultural evolution can be connected with future thinking and sustainability education as well as social-emotional and cooperative learning	Presentation; Tip for the visit of museums of prehistory/early history; cultural evolution analogy table; Video: Michael Muthukrishna - Innovation in the collective brain	Mid-Semester Feedback Survey	Caldwell & Millen (2008); GDSU (2013); Graf & Schmidt-Salomon (2017); Hanisch & Eirdosh (2022a,b); Morgan et al. (2015); Muthukrishna & Henrich (2016); Pugh et al. (2014); Whiten et al. (1999); Whiten & van Schaik (2007)

	Domestication and agriculture	Domestication and agriculture are special cases of coevolution and symbiosis. We are not the only species with agriculture. Simulation games and stories can be used to transfer to the concept of artificial selection. Domesticated animals and plants can be used to explore concepts of evolution (phylogeny, variation, inheritance, function, selection, coevolution). Evolutionary concepts and processes can be explored in school gardens, such as through seed saving/plant breeding. Domestication and agriculture have impacted human evolution, e.g. lactose intolerance.	Presentation; Reflection: hypotheses about the domestication of cats and dogs; comparing natural and artificial selection; comparing agriculture of humans and leaf cutter ants; Videos and images about the differences between domesticated plants and their wild counterparts.		Hanisch & Eirdosh (2022a,b); Mueller et al. (1998, 2005); Fenner (2013); Fenner & Lammert (2011); Russell & McGuigan (2019)
	Religion and science	Several reasons appear to be responsible for a lack of acceptance of evolution in society. The Beutelsbach Consensus as a guideline for dealing with religion in evolution education. Religion/spirituality and science do not need to be irreconcilable. Religion is an evolved human (behavioral and cultural) trait.	Presentation; Beutelsbach Consensus; Big History Project Origin Stories		Becker (2017); Bertka et al., (2019); Big History Project (2019); Billingsley et al. (2019); Graf & Schmidt-Salomon (2017); LPB (1976); Waschke & Lammers (2011)
Unit 3: Social- emotional learning - Application of concepts to themes related to social-emotional competencies					

9	Emotions	Emotions are traits we can explore with the help of evolutionary concepts (esp. common ancestry, functions). Understanding the common descent and functions of emotions can help foster emotional competencies.	Presentation; local ethics curriculum; Movie Inside Out and associated teaching approaches	Small group discussion: what is an emotion Small group activity: discussion of evolutionary origins, functions and mechanisms of basic emotions	Cowen & Keltner (2017); GDSU (2013); Hanisch & Eirdosh (2022a,b)
10	Mismatch, individual-level adaptation, learning	Mismatch describes the negative consequences that can result when the environment changes and traits that were adaptations to past environments do not fulfill their original functions anymore. Many current challenges of human health and sustainability could be considered an instance of mismatch. Humans can overcome mismatch by adapting behavior or changing the environment. Learning is an important process of adaptation.	Presentation; Zoom break-out rooms and shared Google docs;	Small group discussion: What is mismatch; Small group discussion: Possible instances of evolutionary mismatch for humans today; Small group activity: analogy mapping between evolution and learning processes	Baumeister & Robson (2021); Brenner et al. (2015); GDSU (2013); Gluckman et al. (2019); Graf & Schmidt-Salomon (2017); Hanisch & Eirdosh (2022a,b); Lehrer & Schauble (2012); Li et al. (2018); Lloyd et al. (2011); Marquardt-Mau & Rojek (2011); Robertson et al. (2013); Sbarra et al. (2019); Soga & Gaston (2016)
	DNA-V model		Presentation; Connect PSHE and AIM curriculum materials on DNA-V; AIM curriculum materials; Evolution of language/thinking	Reflections: What are values; What is mindfulness	Ciarrochi & Hayes (2018); Connect PSHE (2021); Dixon & Paliliunas (2017); Hayes & Ciarrochi (2015); Porosoff & Weinstein (2019)

11	Cooperation, sense of fairness/ morality		Instructional methods: cooperation games; reflections on fairness	Reflections on how to structure project group work in order to maximize cooperation and motivation	Atkins et al. (2020); Haidt (2012); Hanisch et al. (2020); Hanisch & Eirdosh (2022a,b)
12- 14	Project group work (creation of lesson or unit)				
15				Presentation and discussion of projects; Final reflections	