C·E·P·S Journal

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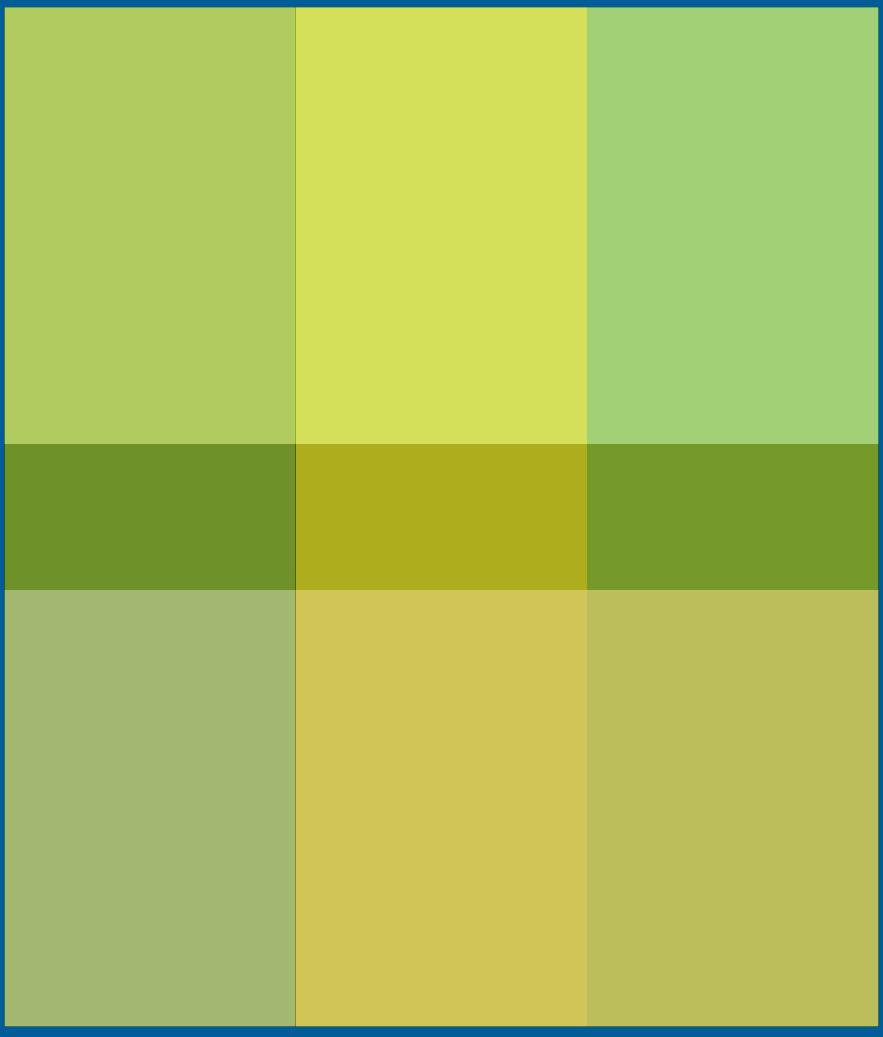

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C·E·P·S *Journal*

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The CEPS Journal is an open-access, peer-reviewed journal devoted to publishing research papers in different fields of education, including scientific.

Aims & Scope

The CEPS Journal is an international peer-reviewed journal with an international board. It publishes original empirical and theoretical studies from a wide variety of academic disciplines related to the field of Teacher Education and Educational Sciences; in particular, it will support comparative studies in the field. Regional context is stressed but the journal remains open to researchers and contributors across all European countries and worldwide. There are four issues per year. Issues are focused on specific areas but there is also space for non-focused articles and book reviews.

About the Publisher

The University of Ljubljana is one of the largest universities in the region (see www.uni-lj.si) and its Faculty of Education (see www.pef.uni-lj.si), established in 1947, has the leading role in teacher education and education sciences in Slovenia. It is well positioned in regional and European cooperation programmes in teaching and research. A publishing unit oversees the dissemination of research results and informs the interested public about new trends in the broad area of teacher education and education sciences; to date, numerous monographs and publications have been published, not just in Slovenian but also in English.

In 2001, the Centre for Educational Policy Studies (CEPS; see http://ceps.pef.uni-lj.si) was established within the Faculty of Education to build upon experience acquired in the broad reform of the national educational system during the period of social transition in the 1990s, to upgrade expertise and to strengthen international cooperation. CEPS has established a number of fruitful contacts, both in the region – particularly with similar institutions in the countries of the Western Balkans – and with interested partners in EU member states and worldwide.

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Revija Centra za študij edukacijskih strategij je mednarodno recenzirana revija z mednarodnim uredniškim odborom in s prostim dostopom. Namenjena je objavljanju člankov s področja izobraževanja učiteljev in edukacijskih ved.

Cilji in namen

Revija je namenjena obravnavanju naslednjih področij: poučevanje, učenje, vzgoja in izobraževanje, socialna pedagogika, specialna in rehabilitacijska pedagogika, predšolska pedagogika, edukacijske politike, supervizija, poučevanje slovenskega jezika in književnosti, poučevanje matematike, računalništva, naravoslovja in tehnike, poučevanje družboslovja in humanistike, poučevanje na področju umetnosti, visokošolsko izobraževanje in izobraževanje odraslih. Poseben poudarek bo namenjen izobraževanju učiteljev in spodbujanju njihovega profesionalnega razvoja.

V reviji so objavljeni znanstveni prispevki, in sicer teoretični prispevki in prispevki, v katerih so predstavljeni rezultati kvantitavnih in kvalitativnih empiričnih raziskav. Še posebej poudarjen je pomen komparativnih raziskav.

Revija izide štirikrat letno. Številke so tematsko opredeljene, v njih pa je prostor tudi za netematske prispevke in predstavitve ter recenzije novih publikacij.

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Izdajanje revije v letih 2015 in 2016 sofinancira Javna agencija za raziskovalno dejavnost Republike Slovenije v okviru Javnega razpisa za sofinanciranje izdajanja domačih znanstvenih periodičnih publikacij.

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The theme of this issue of the CEPS journal is *Challenges for Biology Education in the 21st Century*. In recent decades, biology has evolved from a classical (descriptive) to modern (explanatory) science. Following the era of engineering (19th century), chemistry and physics (20th century), biology has started to play a key role in tackling the global/complex problems of the 21st century. These problems or challenges must be tackled in an integrative way. Integrating knowledge from various disciplines will permit deeper understanding of biological systems and help us find better biology-based solutions to societal problems. The main purpose of this issue is a discussion of the challenges biology educators face with new discoveries and global ecological and societal changes. In the thematic part of this issue, five papers from authors from Finland, Germany, Ireland, Slovenia, and the United Kingdom, discuss the abovementioned challenges with which biology education is faced.

In the first article, entitled *Education for Sustainable Development, Nature and Vernacular Learning*, David Selby discusses the limitations mainstream education for sustainable development has in relation to the perception of the natural world. He argues that the natural world is accorded only instrumental or utilitarian value. This de-natured nature of education for sustainable development makes it unlikely that the learner will become motivated to care and act for nature; therefore, the author proposes an alternative, vernacular learning, i.e. place-based learning rooted in close intimacy and connection with the natural world, with nature perceived as intrinsically valuable. Practical examples of vernacular learning activities are enumerated in the article, in which the importance of nurturing a sense of wonder and joy in the young learner is put forward as vital in fostering an ethic of concern for the planet. Among others, the author is calling for children to become feral (i.e. released from captivity and domestication) and learn to be denizens, something just as important as learning to be citizens. In fostering learning for denizenship, biology education has a crucial part to play.

In the second article, entitled *Professional Competence of Student Teachers to Implement Species Identification in Schools – A Case Study from Germany*, Petra Lindemann-Matthies, Martin Remmele and Eija Yli-Panula investigate how well prepared student teachers are to implement species identification in school. They present results showing that participating student teachers identified plants mainly by flower characteristics and leaves, and animals mainly by shape and colour. The number of correctly identified plant and animal species increased with student interest in identifying species and participation in

species identification courses. The authors emphasised the crucial role of the initial teacher preparation system in familiarising graduate students with local organisms, and with suitable approaches on how to carry out species identification later in school. The authors concluded that in times of an increasing loss of biodiversity is important that teachers are able to familiarise their pupils with species. They are convinced that qualified teachers should at least be familiar with common wild plants and animals in their neighbourhood, in order to understand and teach the very nature of biodiversity. For a majority of people, naming, for example, one hundred species of animals is far from a trivial task. This demonstrates well what our real (societal) interest in nonhuman entities is, as the estimated total number of eukaryote species on Earth is over 8 million (Mora et al., 2011).

The next three articles explore different aspects of perception of scientific biological concepts. The article by Darja Skribe Dimec and Jelka Strgar entitled *Scientific Conceptions of Photosynthesis among Primary School Pupils and Student Teachers of Biology* presents scientific conceptions of photosynthesis, by far the most important biochemical process for the vast majority of organisms on the Earth. The authors explored the scientific conceptions about photosynthesis held by primary school pupils and student teachers of biology in Slovenia. They found that these two groups differ greatly concerning scientific conceptions of photosynthesis. The student teachers showed good and complex understanding of photosynthesis, while pupils showed misconceptions. Analysis of the development of scientific conceptions about photosynthesis with age showed that there is very little progress among primary school pupils. In conclusion, the authors suggest that student teachers should have more direct work with pupils during their study in order to be aware of the problem and to better understand the origin of pupils' misconceptions.

In the article entitled *Fragmented Knowledge and Missing Connections between Knowledge from Different Hierarchical Organisational Levels of Reproduction among Adolescents and Young Adults,* Andrej Šorgo and Rebeka Šiling present the results of a study conducted among students of secondary and tertiary schools on a number of tasks covering reproduction from the molecular to organism level. Their knowledge was seriously flawed. Students had difficulties in building a consistent body of knowledge on the genetic–inheritance axis, and expanding it to the anatomy and physiology of reproduction. Teaching about reproduction is not only a classical biological topic, essential for understanding the phenomenon of life, but is, especially in the case of human reproduction and sexuality, an urgent socio-scientific issue; therefore, the authors contemplate the quality of biology subjects in primary and secondary

schools, being aware that for the greatest number of citizens this will be the last formal contact with some key topics, perhaps influencing their life decisions.

In the third article exploring scientific biological concepts, entitled *Personal Constructions of Biological Concepts – The Repertory Grid Approach*, Thomas J. J. McCloughlin and Philip S. C. Matthews discuss repertory grid analysis as a mathematical tool for investigating the structures of students' representations of biological concepts. Repertory grid analysis provides the researcher with a variety of techniques that are not associated with standard methods of concept mapping for investigating conceptual structures. The technique can be used diagnostically and allows the teacher to gain a visual impression of how a student's concepts are related to each other. It can be used to give an overview of the conceptual structures of a class group. The biological concepts covered in this article are 'natural kinds': a technical class of concepts which 'appear' to have invisible 'essences', meaning they carry more perceptual weight than being perceptually similar. The authors outline one case-study in a small group of secondary school students exploring the concept of 'equine' – that is, what is an equine? In the conclusion, recommendations are offered in applying this approach to biological education research. The authors emphasise that the educator can gain an appreciation of how ideas are modelled or structured by the students. In all these respects, repertory grid analysis can be used by researcher and teacher alike to evaluate teaching and learning.

Practical work in science and biology education is seen as a way to learn practical process skills (e.g. laboratory skills), to learn scientific results, how scientific knowledge is produced and also to enhance students' motivation and interest (White, 1996; Millar, 2010). However, less is known about other affective learning outcomes. The article *Dissection of Mammalian Organs and Opinions about It among Lower and Upper Secondary School Students* by Andreja Špernjak and Andrej Šorgo is a valuable contribution to understanding this aspect of practical work in biology education. The article describes the results of a study that investigated the use of the dissection of mammalian organs in anatomy and physiology classes in Slovenian lower and upper secondary schools. Students' opinions on the dissection of mammalian organs during the courses on human anatomy are positive, and only a minority of students would prefer to opt out. The authors discuss how these practical activities should be presented or replaced by alternatives such as 3D models and virtual laboratory.

There are two articles in the Varia section. The first is by Mojca Žveglič Mihelič, entitled *Assessment Accommodations for Foreign Pupils in the Light of Educational Justice: Empirical Research among Slovenian Primary School Teachers*, and presents the findings of an empirical study on teachers' perspectives on

assessment accommodations for foreign pupils. The results show that teachers who have recent experience of teaching foreign pupils are more aware of the need for assessment accommodations than those who do not. The majority of the teachers accommodate assessment and grading even after the two-year period (i.e. the period of allowed adjustments), and some of them have lower expectations with regard to achieving knowledge standards for these pupils. While the majority of the teachers perceive accommodated assessment as being just, they are unsure of whether the period of allowed adjustments should be longer. This raises the questions about teachers' understanding of educational justice and the application of the principle of justice in practice.

In the second article in the Varia section, entitled *The Role of Cultural Capital in Higher Education Access and Institutional Choice*, Iva Košutić explores perceptions of social inequalities in school achievement and the educational decision-making of the final-year students of secondary schools in the City of Zagreb and Zagreb County, Croatia. The author builds on the theoretical framework of Bourdieu's theory of cultural and social reproduction. The main objectives were an analysis of the association between the students' cultural capital and their school achievement and analyses of the predictive power of the cultural capital theory in the context of educational decisions in the transition to tertiary education. The results indicated that cultural capital had statistically significant correlation with school performance. A detailed presentation of results and discussion tend to support Bourdieu's theory of cultural reproduction through education.

A book review completes the contents of the issue. The book is entitled *Multiple Representations in Biological Education, Models and Modeling in Science Education* (2013) by editors David F. Treagust and Chi-Yan Tsui, published by Springer (ISBN: 978-94-007-4191-1).

Gregor Torkar and Milan Kubiatko

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Education for Sustainable Development, Nature and Vernacular Learning

David Selby[1]

Mainstream education for sustainable development conceives of nature as a resource or commodity. The natural world is, for the most part, accorded only instrumental or utilitarian value. As a field it thus aligns itself with a longstanding paradigm in western thinking that sees humans as separate from and dominant over nature. The de-natured nature of education for sustainable development makes it unlikely that the learner will become motivated to care and act for nature. As an alternative, vernacular learning is proposed, i.e. place-based learning rooted in close intimacy and connection with the natural world, with nature perceived as being intrinsically valuable. The importance of fostering emotional affinity with nature is underlined, as are forms of multi-sensory learning that help the learner engage with both spirit and soul of place. Practical examples of vernacular learning activities are enumerated. The importance of nurturing a sense of wonder and joy in the young learner is put forward as vital in fostering an ethic of concern for the planet. Essentially, the argument goes, we only stir ourselves to protect what we have come to love, and thus cultivating a sense of oneness with nature is vital if we are to have any chance of transforming the global environmental condition. Passion is the harbinger of activism.

Keywords: education for sustainable development; instrumental valuing; intrinsic valuing; nature connection/intimacy; sense of wonder; vernacular learning

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Izobraževanje za trajnostni razvoj, narava in vernakularno učenje

David Selby

V izobraževanju za trajnostni razvoj prevladuje pojmovanje narave kot vira ali surovine. Večini naravnega sveta sta dodeljeni le instrumentalna in utilitarna vrednost. Kot področje se tako povezuje z dolgoletno paradigmo v zahodni misli, ki ljudi dojema kot ločene od narave in dominantne v odnosu do narave. Denaturalizirana podoba narave, ki prevladuje v konceptu izobraževanja za trajnostni razvoj, pomeni, da je manj verjetno, da bo učenec postal motiviran za skrb in delovanje za naravo. Kot alternativa je predlagano vernakularno učenje, tj. učenje, temelječe na spoznavanju lokalnega okolja, zakoreninjeno v tesni povezanosti z naravo, ki je razumljena kot intrinzično pomembna. Pomembnost spodbujanja emocionalne afinitete z naravo je podcenjena, prav tako pa so podcenjene tudi oblike multisenzoričnega učenja, ki pomagajo učencu, da se poveže duhovno in duševno s prostorom. Našteti so praktični primeri vernakularnih učnih aktivnosti. Pomembnost negovanja občutka radovednosti in veselja v mladem učencu je postavljena v ospredje kot tisto, kar je pomembno pri spodbujanju etične skrbi za planet. Argument pravi takole: sami se zganemo za varovanje le tistega, kar smo vzljubili, in zato je negovanje občutka enosti z naravo pomembno, če želimo imeti kakršno koli možnost preoblikovanja globalnih okolijskih razmer. Strast je znanilka aktivizma.

Ključne besede: izobraževanje za trajnostni razvoj, instrumentalno vrednotenje, intrinzično vrednotenje, povezanost z naravo/intimnost, radovednost, vernakularno učenje

Education for Sustainable Development

In the last thirty years the idea of sustainable development has come to be widely advocated as the best hope for alleviating the global environmental condition, a condition marked by the degradation and thinning of ecosystems, huge biodiversity loss, the ubiquitous spread of toxicity, the desertification of land and deadening of oceans, a worsening epidemiological environment for both humans and other-than-humans, depletion of groundwater, and the spoliation of land not least through the outward march of land-devouring urbanisation (Ehrlich & Ehrlich, 2013). Lurking behind and fueling this multi-crisis syndrome, in which crises in the human socio-economic condition also figure prominently, lies stealthy but rapid onset climate change (Selby, 2014, p. 166).

Sustainable development was famously defined in the Brundtland Commission report, *Our Common Future* (World Commission on Environment and Development, 1987, p. 43) as 'development that meets the needs of the present without compromising the ability of future generations to meet their needs,' a definition that continues to enjoy wide currency. It is generally depicted as a process of maintaining a dynamic balance between three interrelated 'pillars,' or 'dimensions', i.e. economy, environment and society as the development process is taken forward, with the aim of staying within the constraints imposed by the 'carrying capacity' of the planet.

At the 2014 conference in Aichi-Nagoya, Japan, wrapping up the 2005-14 UN Decade of Education for Sustainable Development (DESD), education for sustainable development (ESD) was declared to be an 'enabler for sustainable development' with the potential to 'empower learners to transform themselves and the society they live in' (UNESCO, 2014a). The *Global Action Programme on Education for Sustainable Development*, designed to provide the roadmap for the post-2015 ESD agenda and launched at the conference, rehearses the core learning content, approaches and competencies of ESD:

- It involves developing in the learner the knowledge, skills, values and attitudes enabling informed decision making and responsible action for environmental integrity, economic viability and the just society in the present and with an eye to the future;
- It entails the use of participatory learning and teaching methods that motivate and empower learners;
- It is fundamentally a rights-based approach;
- It relates to the environmental, social and economic pillars of sustainable development in an integrated, balanced and holistic way, comprehensively embracing, *inter alia*, poverty reduction, climate change,

disaster risk reduction, biodiversity and sustainable consumption and production;

- It encompasses but does not seek to usurp historical and/or current 'adjectival' educations such as environmental education, global education and development education (UNESCO, 2014b, p. 33).

From the perspective of anyone concerned about the wellbeing of the natural world, ESD would seem at first glance to offer an auspicious agenda. The environment, it would appear, figures significantly. A second glance, however, unearths a decidedly anthropocentric vein. 'People,' we are told without further elaboration in the preface to the *Aichi-Nagoya Declaration on Education for Sustainable Development*, 'are at the centre of sustainable development' (UNESCO, 2014a). So where, we might ask ourselves does nature truly stand in the ESD landscape?

A De-naturing of Learning

A word search of recent key international ESD documents, such as those cited above reveals only limited reference to 'nature' and 'natural world'. Rather, nature is referenced through the filter of 'environment', a term derived from the French 'environs', i.e. that which surrounds us but in which we are not necessarily embedded. Only very rarely in the literature searched does the descriptor 'natural' ever precede the term 'environment' thus further confirming the impression of the environmental pillar of sustainable development as a reductively de-natured conception.

The most recent frame-setting international articulation of sustainable development came in September 2015 when the United Nations General Assembly adopted a fifteen-year plan, *Transforming our World: the 2030 Agenda for Sustainable Development*. Described as 'a plan of action for people, planet and prosperity' the *Agenda lays* out 17 interlinked Sustainable Development Goals while enumerating 169 action targets for the collective realisation of those goals. Within the *Agenda* the natural environment is far from overlooked but is reduced in two very specific and significant ways. First, only two out of the 17 goals relate directly to the natural condition, i.e. Goal 14 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development' and Goal 15 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'. Second, as evident in the two goals just referred to, nature is comprehensively looked at through management and resource lenses. The lexicon of the *Agenda* abounds with terminology

such as 'sustainable use', 'conservation for development', 'environmentally sound management', 'science-based management', 'natural resources' and 'sustainable management' (UN General Assembly, 2015).

Shaping the Future We Want, the final monitoring report from the UN Decade of Education for Sustainable Development (UNESCO, 2014c), overviews outcomes of global efforts to implement sustainability-oriented learning. Here we do find references to 'nature' and 'natural world' and descriptions of learning programs that actively engage students with and in nature but, significantly, most of the references made and examples described occur in the report sub-section devoted to early childhood care and education (pp. 68–78) with just a few examples in a sub-section on non-formal education (especially, p. 136). Elsewhere in the report, including in the sub-section on primary and secondary pedagogy, there is but scant consideration of nature-related learning. Throughout the report nature is frequently conceived of as 'resource' requiring sound 'environmental management' and calling for 'sustainable use'.

Overall, the letter and the spirit of such documents tend to underline the *instrumental* valuing of nature that has characterised sustainable development from the outset (Selby, 2007a, pp. 256–257). The field has, for the most part, abstracted and objectified the natural world, its discourse suggesting a preponderantly utilitarian, commodifying, and exploitative conception in which nature has been referred to variously as 'resource', 'natural capital' and 'ecosystem service' (Selby & Kagawa, 2014, p. 146). There are clearly advocates of sustainable development, especially environmentalists coming latterly to the field, who do make token acknowledgement of the *intrinsic* value, both tangible and intangible, of ecosystems and other-than-human animate entities (i.e. as having value in their own right apart from any usefulness to humans). But, cognizant of the primacy given to economic growth in sustainable development discourse (ibid. 143–146), they tend to seek purchase and influence by marshalling the case for nature conservation based upon an instrumentalist rather than intrinsic valuing of the natural world. In this way, sustainable development coincides with the development of the field of environmental economics. The global (but rich world funded) Economics of Ecosystems and Biodiversity (TEEB) project has as its rationale the protection of natural diversity by placing a financial value on 'biodiversity and ecosystem services' so that both their maintenance and loss can be factored into governmental decision-making. By making the economics of nature visible, the thinking goes, governments will be better motivated to protect the natural world in pursuance of their own self-interest (TEEB, 2016).

There are profound concerns here. First, adherents of both sustainable development and environmental economics align themselves with a flawed

paradigm that sees the human being as separate from, higher than and dominant over nature, the paradigm that has brought the natural world to the emasculated state in which we find it today (Selby, 2007b, pp. 165–167). In the name of sustainable development, they collude with the disease and, in dressed-up form, recommend the disease as cure. Brian Swimme and Thomas Berry (1992, p. 199) describe the paradigm as a kind of 'exaggerated anthropocentrism' emerging from the late-medieval/early modern western world in which the 'mystical bonding of the human with the natural world was progressively weakened' and in which 'Earth was no longer seen as a communion of subjects' but became a 'collection of objects to be adjusted to in an external manner'. That view pervades sustainability discourse. In seeming to protect nature on grounds of usefulness and by commodification of elements making up the natural world, the way is opened for nature to be 'traded, speculated on, and ultimately owned and controlled' (McCarthy, 2015, p. 27). Each element deemed useful becomes a line in a ledger while each element held to be of no particular or self-evident utilitarian or financial value stands to be set aside and discounted. What value, Michael McCarthy asks do we give to butterflies, to birdsong? 'Are they just to be written off, as the great ruination of nature gathers pace?' (ibid. p. 28).

'Today's environmentalism is as much the victim of the contemporary cult of utility as every aspect of our lives,' writes Paul Kingsnorth (2012, no pagination).

> We are not environmentalists now because we have an emotional reaction to the wild world. […] We are environmentalists now in order to promote something called "sustainability". What does this curious, plastic word mean? It does not mean defending the nonhuman world from the ever-expanding empire of Homo sapiens sapiens though some of its adherents like to pretend it does, even to themselves. It means sustaining human civilization at the comfort level that the world's rich people – us – feel is right, without destroying the "natural capital" or the "resource base" that is needed to do so.

Second, there are serious concerns as to whether education rooted in a conception of sustainable development that, in the name of scientific exactitude and economic imperative has pushed aside the poetic and visionary can ever help the learner identify with nature and become motivated to care for and act for nature. In the final analysis, sustainable development is a dry, abstract concept far removed from lived, immersed experience. It can engage the intellect, the cerebral, but not the emotions. 'No one is going to stir the soul with sustainable development, no one is going to write poems about TEEB […] both are

mere intellectual constructs; they can fill the minds of policymakers, but they cannot reach the hearts of people' (McCarthy, 2015, p. 245). The problem with ESD is that it follows its parent field in its essential instrumentalism and rationalism. Marginalised or missing are notions of human entanglement in nature, human enrichment through nature experience and emotional engagement with nature. Largely absent from its discourse are concepts that lend themselves to embedded affinity with nature such as beauty, attunement, awe, ecstasy, enchantment, intuition, reverence, rhapsody, joy and wonder. The emphasis is almost exclusively on what nature can do *for us* rather than on what nature can do *to us* (Macfarlane, 2015, p. 25).

Let us explore these ideas further and how we might develop learning that opens the way for a renewed intimacy with nature as an alternative or at least counterpoint to utilitarian justification.

Vernacular Learning

Laurie Lee in his childhood autobiography *Cider with Rosie* (1974) recalls in vivid and close detail life in a remote English village in the immediate aftermath of the First World War, a seemingly timeless place but on the verge of intrusion by cars and electricity. He gives a memoir of a boyhood spent in fields, lanes and woods, a life wrapped up in the comings and goings of local folk. 'Winter and summer dominated our every action, broke into our houses, conscripted our thoughts, ruled our games, and ordered our lives' (ibid. p. 136) and so much so that they were conceived of as almost different places, not different times of year. 'There were ghosts in the stones, in the trees, and the walls, and each field and hill had several. The elder people knew about those things and would refer to them in personal terms, and there were certain landmarks about the valley – tree-clumps, corners in woods – that bore separate, antique, half-muttered names' (ibid. p. 105). Place was alive and storied.

What Lee describes is a young life lived in 'porous exchange' (Marren, 2015, p. 191) with immediate nature. As such, place in its diversity came alive and fed into psyche. There were words for everything so that trees were not just trees but particular representatives of particular tree species around which story was invented, memories preserved and passed on to future generations. There was animism within experience. Contrast the riches of connective stimulus open to Lee with the fact that the newest edition of the *Oxford Junior Dictionary* has withdrawn a long list of nature words no longer considered relevant to modern childhood – words such as ash, beech, bluebell, buttercup, cowslip, dandelion, mistletoe, willow – replacing them with words of the indoor and virtual worlds

such as blog, broadband, bullet-point, cut-and-paste and voice-mail (Flood, 2015; Macfarlane, 2015, p. 3). Contrast them, too, with the reduced experience of many millions who can no longer name and describe particular natural and physical entities in their environment nor perceive their distinctiveness but have recourse to generic descriptors such as 'hill', 'valley' and 'wood', thus relegating landscape to 'blandscape', as Robert Macfarlane (ibid. p. 23) puts it. If, to borrow from Maurice Merleau-Ponty (1962, p. 24) landscape is not so much the object as 'the homeland of our thoughts', then a pared-down ability to relate to landscape is both cause and consequence of reduced imagination, impaired sensibility and curtailed vision. For Macfarlane (2015, p. 10), 'to celebrate the lexis of landscape is not nostalgic, but urgent'. It is the harbinger of environmental concern and activism. He cites Wendell Berry (2000, p. 41): 'People *exploit* what they have merely concluded to be of value, but they *defend* what they love and to defend what we love we need a particularizing language for we love what we particularly know'.

Ultimately, then, we care most about what we know intimately and deeply. This speaks to a curriculum of successive, repeated, locally grounded learning experiences that foster a sense of belonging. Rob Cowen writes (2015, p. 205):

> Familiarity comes with the overlaying of our experiences, memories and stories: *there's the stretch of river where the mayfly rose; that's the owl's nesting tree; these hedgerows were once the boundaries of enclosure.* We project all we are and all we know onto landscape. And, if we're open to it, the landscape projects back into us. Time spent in one place deepens this interaction creating a melding and meshing that can feel a bit like love. In the drowsy light of the coming evening I not only see where I've walked before, but who I was when I walked there. What I was feeling; what I was thinking. And isn't this how we navigate the sphere? Creating fusions of human and place, attaching meaning and emotions, drawing cognitive maps that make sense of the realm beyond our comprehension? Our connection to the world is always two things: instinctive and augmented (italics in original).

Connection to place, we note, integrally involves the dynamic interplay of space and time.

Informed largely by scientific and technocratic frames of reference, education for sustainable development is doing little to overturn the 'dissociation of sensibility', the 'breaking up of the ability to feel and relate to life' that set in at the time of Galileo Galilei (McIntosh, 2008, p. 154). Rather, it has colluded with the ongoing estrangement of humanity from nature. And yet, it is a sense of oneness with nature that is likely to translate into transformative action and transformed

ways of being in the world. Noel Charlton (2008, p. 160) argues that 'the only social process that seems potentially able to override the consumerist, aggressive, power-hungry ethic that is prevalent now, seems to be a psychological dynamic oriented towards the sacred nature of the total ecology'. That dynamic is likely to be most keenly felt through an intimate relationship with the nested entity that is the local place. Kingsnorth (2012, no pagination) writes:

> Global campaigning for an abstract "environment" does not appear to work. What does work is engaging with nature on a human scale. Perhaps the best rejoinder to those who believe that the world is a giant spreadsheet is an engagement with its messy everyday complexity. A kind of vernacular environmentalism: and engagement not with "the environment," but environments as we experience them in lived reality. Perhaps it is time to go back to basics.

Those 'basics' might involve learners in going out and perceiving ambient fauna and flora through the seasons and asking of climate change, as Canadian children might: 'Do we really want to lose the piping plover, the boreal clintonia, snow, the return of spring?' (Pruneau et al., 2001, p. 135). They might also include:

- Frequent and detailed observation of the fauna and flora in an uncultivated square metre of land accompanied by log writing and sketching;
- Indigenous meadow restoration and maintenance linked to close observation of the emerging meadow ecosystem;
- Examining past accounts and stories, sketches and photographs of place, revisiting storied locations and landscape features, looking for the signature of the past, with learners imagining inhabitation of bygone days;
- Creating school butterfly and bee gardens linked to maintaining a log of insect appearances;
- Conducting a weekly local butterfly transect through spring, summer and autumn months, maintaining records and returning to past records to discern and analyse trends in the frequency of sightings of species (making findings known in the name of citizenship science);
- Replanting and re-wilding projects;
- Harvesting and preparing wild food;
- Developing and maintaining an organic school garden combined with orchard and apiary and exploring the process and biology of food production;
- Joining localized chains of food production as growers, preparers and end-users;

- Learning weaving, woodwork, pottery and other craft skills using materials that learners harvest locally;
- (In areas not subject to light pollution), keeping a record of the movement of star constellations in the night canopy;
- Keeping weather logs, making comparisons year by year, and having learners experience and respond to weather diversity;
- Translating local specimens as viewed under the microscope or through a magnifying glass or as startlingly revealed through binoculars into detailed sketches and descriptive text (and so registering the exquisite beauty of nature in its micro detail);
- Helping revive forgotten or lost local forms of nature celebration;
- Researching local vernacular nature terminology that has fallen into disuse; having learners invent a new vernacular lexicon for places they explore and map (Macfarlane, 2015, p. 326);
- Searching out and observing wildlife in urban contexts;
- Re-naturalizing and re-wilding urban parks and brownfield sites, using them as study focus.

In implementing all such activities there should be encouragement to learners to exercise sensory perception as they strive to engage with the *genius loci*, the spirit of place, and the *anima loci*, the soul of place, as manifest in both the animate and inanimate and in the wider ecosystem. Matthew Shaw (2016, p. 28) advocates a harkening to the spirit of place:

> Stones, natural springs, trees, birds, valleys, mountains and even conurbations all have this soul present. Exploring sounds, sights, smells, words, song and feelings gives an opportunity to explore what is hidden below the surface and first impressions. A device to notice more, hear more, to reflect on what a space has to say. What energy is present? What emotions or memories are evoked and stimulated?

In sensory cultivation, the practicing of synaesthesia with learners can be very powerful although it can be, in its counter-rationalism, initially demanding, i.e. the stimulation of a sense impression relating to one sense through the channel of another sense. Ask the class: What colour is the spring birdsong? What taste does a dark sky have? What is the mood of the grain in the rock? What is the sound of blossom in the hedgerows? Landscape, then, 'should not be seen as still or passive; it exists embedded within an ontological web of personal and cultural narratives, collective memory and its sensory associations that are awakened through our engagement with the environments

they embody' (Outcasting Fourth Wall, 2014, no pagination).

There may well be objections to what I advocate. First, there could very well be misgivings on the grounds that rampant urbanisation has taken away direct experience of nature from increasing numbers of children and that what I propose can only apply to rural or small town children, now a minority. But there is intimate nature to be found in an urban context, the explosion of the urban fox population, the return of the otter to rivers flowing through urban areas and the nesting of the once threatened peregrine falcon on inner-city high-rise buildings being landmark examples. Furthermore, many of the learning proposals made above can indeed be implemented in urban contexts. Many an urban school can establish a garden or farm for nature study; schools can become local hubs for re-wilding and nature restoration projects, also using their own grounds; schools can provide learners with sensory experience of nature through study time spent in parks and gardens.

Second, some might take exception to what is proposed here as inappropriate learning for life in an economically and otherwise globalised world that increasingly pervades our lives - a condition, we might add, that is less than critically scrutinised by mainstream articulations of education for sustainable development (Selby, 2015, pp. 26–27). But this is to collude with the denigration of parochialism that has proceeded apace in the last century so that it has come to connote 'sectarianism, insularity, boundedness: a mind or a community turned inward upon itself, a pejorative finitude' (Macfarlane, 2015, p. 62). For the great Irish poet, Patrick Kavanagh, close observer of fine detail in the mundane, deep parochial insight is the surest means of connecting with the universal flow of things, of establishing solidarity with how lives are largely led around the world. 'Parochialism is universal and deals with the fundamentals,' he wrote in his great essay of 1952, 'The Parish and the Universe' (Kavanagh, 1967, pp. 281–283). Kavanagh saw the parish not as 'a perimeter but an aperture: a space through which the world could be seen' (Macfarlane, 2015, p. 62). For John Tomaney (2012, p. 658), 'the local, its cultures and its solidarities are a moral starting point and a locus of ecological concern in all human societies and at all moments of history'. While the globalisation impulse closes us off from our surroundings as moral source, deep sense of place arising out of a focus on the small, the particular and the specific carries within itself the potential to link the learner to the universals in human experience (Brackenborough, 2015).

Third, some might demur that there is something overly idyllic, decidedly soft and romantic, about my depiction of nature and its effect on the learner. This is not the case. In the first place intimacy with nature has to be worked at. There is no instant return or gratification from sitting in a wood 'watching nature'.

It is, rather, a process that runs counter to the swift pace of learning to which most students are now remorselessly acculturated, an acculturation from which education for sustainable development has never seriously broken free under the influence of the disciplines that have led the way in its conceptualisation, i.e. economics and the environmental and social sciences. A discipline of slow learning is called for as a means of attuning to nature. 'The natural world is really slow,' writes Jerry Mander (1991, p. 86). 'Save for the waving of trees in the wind, or the occasional animal movement, things barely happen at all. To experience nature, to feel its subtleties, requires human perceptual ability that is capable of slowness. It requires that human beings approach experience with patience and calm.' Vernacular learning in nature also involves experiencing the inhospitable, the unappealing, the uncomfortable. 'It is this endurance of everything that nature throws at us,' writes the Lakeland philosopher shepherd James Rebanks (2016, p. 226), 'that shapes our relationship with this place. We are weathered like the mountain ash trees that grow here.' That 'weathering' can be about experiencing nature in winter cold and storms. It can also be about understanding and coming to terms with the cycle of birth, growth, decay and death that afflicts all elements in the natural world, including ourselves. Cycles of birth and death are central to an ecological worldview. Death denial arguably foments our planetary crisis of unsustainability. We consume and rush for a reprieve from loss and death, to dull the experience of the world as it in fact is (Griffin, 1995, pp. 51–52).

Learning in and through Wonder and Joy

To sum up thus far, I have suggested that education for sustainable development, at least in its mainstream conception, marginalises nature, enshrining a valuing of the natural world that is instrumental. In so doing any educational contribution to the wished-for transformation of the global environmental condition is likely to remain out of reach. My proposal is to build a sense of oneness and intimacy with nature through learning that is local and vernacular and that fosters an empathetic and emotional bonding with place. In her lyrical and oft-reprinted essay, *The Sense of Wonder*, written in 1956, Rachel Carson reminds us of how important wonder is to the life experience of the child. She reminds us too that the child intuitively apprehends and adheres to a truth that adults easily seem to forget – that we are all part of the natural world. She writes (1998 edition) about how to nurture in the child the freshness of vision and sense of connectedness with which each of us first saw the world. 'If a child is to keep alive his (sic.) inborn sense of wonder,' she counsels parents, 'he needs the companionship of at least one adult who can share it, rediscovering with

him the joy, excitement and mystery of the world we live in. […] I sincerely believe that for the child, and for the parents seeking to guide him, it is not half so important to *know* as to *feel*' (ibid. p. 55). Thus wrote the great biologist and conservationist, author of the world-changing 1962 classic *Silent Spring* (2000).

Without a nurtured sense of wonder, an appreciation of nature and resolve to preserve beauty and diversity in this world can easily become constricted as the child moves towards adulthood. For lepidopterist Michael McCarthy, dry, rational, sustainable development will not halt the impoverishment and despoliation of the planet but the cultivation of joy and love through nature engagement – leading in turn to commitment to defend that in which we delight – might. Joy through nature – joy being defined as a form of 'concentrated happiness' (McCarthy, 2015, p. 195) – can revive the 'ancient bond with the natural world surviving deep within us […]part of our essence […] the natural home for our psyches' (ibid. p. 246).

All the above is in contradistinction to the ethos of an education for sustainable development that rarely gives space for poetic and numinous insight, relying overly on scientific rationality. 'At the heart of the matter,' writes Michael Bonnett (1999, p. 321) 'is the question of the adequacy of rationality to resolve issues in an area as complex, subtle and multidimensional […] as environmental concern, not least from the motives embedded in modern rationality *itself*,' expressing, as it does, 'certain aspirations to the world, notably to classify, explain, predict, evaluate and, as far as modern rationality is concerned to exploit it' (italics in original). An alternative, borrowing the title of Eban Goodstein's fine (2007) book, is one of *Fighting for Love in the Century of Extinction.*

Other Educations

If not education for sustainable development as presently manifest, what counterbalancing educational fields exist that have the potential and promise to nurture a biophilic ethic (Wilson, 1984) that affiliates the learner with other life forms through intimate experience of the near-at-hand?

Place-based education takes as its starting point the attunement of the learner to the specific attributes and rhythms of place through curriculum content that focuses upon the geographical, geological, ecological, cultural and sociological. The approach is interdisciplinary, experiential, enquiry-based, and involves, according to many of its advocates, an action component. Key to the approach is that of seeing 'human beings as one part of the natural world and human cultures as an outgrowth of interactions between our species and particular places' (Smith & Williams, 1999, p. 3). It, thus, seeks to revive appreciation

of place-informed culture, something eroded through industrial growth (ibid. p. 4). Place-based education has been labelled 'ecological education', a key principle of which concerns developing 'affinity with the earth through practical experiences out-of-doors and through the practice of an ethic of care' (ibid.).

Bioregional education enjoys a considerable overlap with place-based education, taking as its focus and learning laboratory an area of distinctive geological and natural features that has shaped and informed human cultural expression and practice in that place. 'A critical component of each bioregion is the human culture which has developed within and is integral to that area' (Traina, 1995, p. 3). A bioregion may straddle political boundaries. Within its parameters, adherents theorize that there exists amongst the human population a 'terrain of consciousness,' a shared feeling of identification with natural and cultural influences in their interplay (ibid. p. 4). The kinship and interdependence of the natural and cultural within the bioregion is of core educational concern (ibid. p. 7). 'Bioregional education recognizes no separation of learning from life. […] The process of bioregional education is one of active participation and sharing within the human community and the natural environment. Bioregional education honours the products of the intellect while remaining grounded in a joyful and empowering awareness of spirit' (ibid.).

Outdoor education is by no means locally restricted but most commonly happens near to the home or school base. It is an approach that aims to offer learners meaningful in-situ experience of both natural and constructed environments that complements class learning while also practising enquiry, observational and other skills 'out in the field' (Dillon et al., 2005, pp. 20–21; Woodhouse & Knapp, 2000).

Passion Leading to Activism

Any call for passion for nature allied with passion for place swims against the tide of what is happening to child experience in the contemporary world. Figure 1 below captures the essence of the argument put forward by George Monbiot (2012, p. 30) that we are facing a 'second environmental crisis: the removal of children from the natural world'. Stories of environmental devastation and loss assail us with insistent frequency. But 'where,' he asks, 'are the marches, the occupations, the urgent demands for change?' The problem, he responds, is that 'young people we might have expected to lead the defence of nature have less and less to do with it.'

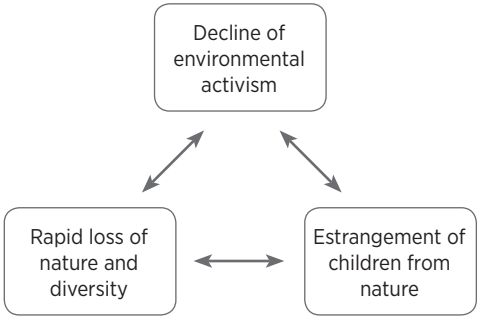

Figure 1. The 'Second Environmental Crisis' (Monbiot, 2012, p. 30)

Monbiot proceeds to enumerate examples illustrative of the 'remarkable collapse of children's engagement with nature – which is even faster than the collapse of the natural world.' Drawing on the work of Richard Louv (2005) on nature deficit disorder in children in the USA (i.e. behavioural problems and hyperactivity, physical and emotional illness resulting from spending little time out of doors) and also on Stephen Moss' 2012 survey, *Natural Childhood*, written for the United Kingdom National Trust, he cites, *inter alia*, the following examples:

- Since the 1970s the 'radius of activity', i.e. the area around their homes in which children are able to roam unsupervised has decreased by almost 90%;
- In one generation the proportion of children in the UK regularly playing in wild places has fallen from more than half to fewer than one in ten;
- In the USA in the period 1997 to 2003, the number of children with outdoor hobbies fell by half;
- 11–15-year olds in the UK spend, on average, half their waking day in front of a screen.

There are myriad factors behind such trends; for instance, safety fears on the part of parents, destruction of the common land on which previous generations of children played, the alluring, addictive quality of indoor electronic entertainment and of virtual worlds and virtual connectivity. But the decline of nature experience matters, writes Monbiot (2012, p. 30), in that 'if children lose contact with nature they won't fight for it'. Estrangement from nature thus clears the way for 'forces which if they cannot be turned, will strip the living planet of the wonder and delight, of the ecstasy – in the true sense of that word – that for millennia have drawn children into the wilds' (ibid). 'Most of those who fight for nature are people who spent their childhood immersed in it,' he notes. 'Without a feel for the texture and functions of the natural world, without an

intensity of engagement almost impossible in the absence of early experience, people will not devote their lives to its protection' (ibid.).

There is, then, a powerful case for the kind of nature learning that education for sustainable development has more or less marginalised. In calling for children to become feral (i.e. released from captivity and domestication) and thus rewilded, Monbiot (2013, p. 169) makes an impassioned plea for a return to the woods:

> Missing from children's lives more than almost anything else is time in the woods. Watching my child and others, it seems to me that deep cover encourages deep play, that big trees, an understory mazed by fallen trunks and shrubs which conceal dells and banks and overhangs, draw children out of the known world and into others. Almost the woods become peopled with other beings, become the setting for rhapsodic myth and saga, translate the children into characters in an ageless epic, always new, always the same. Here, genetic memories reawaken, ancient impulses are unearthed, age-old patterns of play and discovery recited.

The children in the woods are learning to be denizens, dwellers in place, something just as important as learning to be citizens. In fostering learning for denizenship, biology education has a crucial part to play. It can cultivate nature intimacy that fuses the scientific and the aesthetic. It can take learning out into locality. It can develop and hone skills and dispositions for multi-sensory nature learning. It can explore how nature informs cultural expression. It can reveal the miraculous in the mundane – the 'World in a Grain of Sand' and 'Heaven in a Wild Flower' to borrow from William Blake (Hayward, 1968, p. 243). It can help build and deepen learner affinity with and love of nature leading to an ethic of active care and defence of nature, an ethic that is the springboard for activism.

In so doing the biological sciences, reconfigured to give space for slow, multi-sensory learning melding the scientific and the spiritual, can play a potentially crucial role in redressing the de-natured condition of education for sustainable development which, it has been suggested, seeks transformation but ignores the transformative potentials and energies that can be unleashed by a lived and felt relationship of committed engagement with the natural world. Such a reconfigured biology education would also find itself rather closely aligned with what has come to be known as activist or action-oriented science education 'in which students not only address complex and often controversial environmental and socioscientific issues and formulate their own positions concerning them, but also prepare for, and engage in, sociopolitical actions that they believe will "make a difference" ' (Hodson, 2014, p. 68).

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Biographical note

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Professional Competence of Student Teachers to Implement Species Identification in Schools – A Case Study from Germany

Petra Lindemann-Matthies*[1], Martin Remmele[2] and Eija Yli-Panula[3]

This study investigates how well prepared student teachers are to implement species identification in school. Data were collected with the help of a questionnaire and a PowerPoint presentation in which local plant and animal species were presented. Participants (n = 357) correctly identified, on average, 23% of the plants and 44% of the animals. They identified plants mainly by flower characteristics and leaves, and animals mainly by shape and colour. Family and school were key sources of participants' knowledge of species. The self-estimated competence of participants to identify species was positively correlated with their taxonomic knowledge and the amount of time they had spent on species identification during their own schooldays. The number of correctly identified plant and animal species increased with interest in identifying species and participation in species identification courses. Participants considered learner-centred education and experience-based learning, and the use of living organisms to be most important when identifying species in school.

Keywords: biodiversity; species identification; student teachers; curriculum

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Strokovne kompetence bodočih učiteljev za implementacijo prepoznavanja vrst v šoli – študija primera iz Nemčije

Petra Lindemann-Matthies, Martin Remmele in Eija Yli-Panula

Ta raziskava preučuje, kako dobro so bodoči učitelji pripravljeni na implementiranje prepoznavanja živalskih in rastlinskih vrst v šoli. Podatki so bili zbrani s pomočjo vprašalnika in predstavitve v PowerPointu, v kateri so bile predstavljene lokalne rastlinske in živalske vrste. Udeleženci (N = 357) so v povprečju pravilno prepoznali 23 odstotkov rastlin in 44 odstotkov živali. V večini primerov so rastline prepoznali glede na značilnosti cvetov in listov ter živali glede na obliko in barvo. Glavna vira znanja udeležencev o vrstah sta bila družina in šola. Samoocena kompetenc udeležencev za prepoznavanje vrst je bila pozitivno povezana z njihovim taksonomskim znanjem in s količino časa, ki so jo v šoli namenili prepoznavanju vrst. Število pravilno prepoznanih rastlinskih in živalskih vrst se je povečalo z njihovim zanimanjem za prepoznavanje vrst in s sodelovanjem pri predmetih, pri katerih se ukvarjajo s prepoznavanjem vrst. Udeleženci so opredelili, da so za prepoznavanje vrst v šoli najpomembnejši na učenca osredinjeno poučevanje in izkustveno učenje ter uporaba živih organizmov pri pouku.

Ključne besede: biotska pestrost, prepoznavanje vrst, bodoči učitelji, kurikulum

Introduction

Biodiversity has been recognised as an educational priority at all levels of formal education (UNESCO, 2005) and it has been proposed that pupils should be empowered to act in ways that protect and conserve biodiversity (Gayford, 2000; Lindemann-Matthies et al., 2011; Menzel & Bögeholz, 2009; Van Weelie & Wals, 2002). However, pupils might not care about species which they do not know and cannot name (Pilgrim, Cullen, Smith & Pretty, 2008; Weilbacher, 1993). Familiarising pupils with local plants and animals should thus be a fundamental part of biodiversity education in school (Barker, Slingsby & Tilling, 2002; Leather & Quicke, 2010; Lindemann-Matthies, 2005, 2006; Scott et al., 2012). However, teachers might not be well-prepared for this task.

Systematic biology has been drastically reduced in recent decades at European universities (Bilton, 2014; Leather & Quicke, 2009; Swiss Academy of Sciences, 2006), leading to a generation of academics, teachers included, who can barely identify organisms or know their functions (Leather & Quicke, 2009; 2010; Stagg & Donkin, 2013). In a British study, for instance, only a few (student) teachers were able to identify more than three common local wildflowers, which were shown to them as colour illustrations (Bebbington, 2005). Moreover, among biology undergraduates in the UK, a conspicuous decline in both botanical and zoological knowledge has been observed (Leather & Quicke, 2010). The authors concluded that most biology students today have virtually no training or experience in identifying organisms and that the drive towards ever more molecular courses is exacerbating the situation. The 'taxonomic impediment' in higher education (Bilton, 2014) is reinforced by the fact that in industrialised, high-income countries, which are now largely independent of local environmental goods and services, knowledge about species and their functions is no longer needed to sustain people's livelihoods (Pilgrim et al., 2008).

Decreasing knowledge of local biodiversity in highly developed countries (e.g. Balmford, Clegg, Coulson & Taylor, 2002; Bebbington, 2005; Lindemann-Matthies, 2002a, b) is not only due to decreasing educational opportunities, or less dependence on natural surroundings for food or other resources, but also due to a reduction of independent outdoor experiences for children. With increasing urbanisation, 'wild' habitats that children prefer for outdoor play and nature investigations are lost (Louv, 2006), and parental anxiety regarding social and traffic dangers increasingly keeps children indoors (Hüttenmoser, 1995; Prezza, Alparone, Cristallo & Luigi, 2005; Valentine & McKendrick, 1997). Electronic/video games and television also keep children indoors,

thus contributing to a reduction of their autonomous outdoor experiences and knowledge of local organisms (McKendrick et al., 2000). When, for instance, in Switzerland more than 6000 young people between the age of eight and 18 were asked about organisms in their immediate environment, on average five plants and six animals were named and unspecified taxa, such as 'flowers' and 'birds', were among the most commonly listed in all age-groups (Lindemann-Matthies, 2002a).

Familiarising pupils with local plants and animals through relevant experiences in school requires competent teachers. In this paper, we present results from a German case study on the professional competence of primary and secondary school student teachers to implement species identification in school. Our study took place in the federal state of Baden-Württemberg. The state's education plans for both primary and secondary school requiring pupils to be sensitised to the diversity of local plants and animals, and for species conservation. However, the education plans do not provide teachers with a canon of species or a list of groups of organisms, which pupils should know. They also do not refer to certain identification strategies or approaches for species identification. This means that the number and identity of plants and animals pupils will become familiar with, and the ways that species are introduced in school, depend on the individual teacher, and thus on his or her own knowledge of species, identification approaches and commitment to species-identification activities.

The overall goal of the present study was to investigate how well-prepared student teachers are to implement species identification in school. The results contribute to international studies on people's ability to identify species (e.g. Balmford, Clegg, Coulson & Taylor, 2002; Bebbington, 2005; Lindemann-Matthies, 2002a; Lückmann & Menzel, 2014; Palmberg et al., 2015; Randler, 2008), on features used when identifying organisms (e.g. Kos & Jerman, 2015; Tunnicliffe & Reiss, 1999, 2000) and on suitable approaches for species identification in school (e.g. Lindemann-Matthies, 2006; Palmberg et al., 2015; Randler & Bogner, 2002; Scott et al., 2012). The main questions explored in this study were:

(Q1) How familiar are student teachers with local plants and animals and which specific features do they use to identify species?

(Q2) How interested are they in identifying species and from where do they obtain their knowledge (initial teacher education, other sources)?

(Q3) How satisfied are they with their teacher preparation, and how competent do they feel they are to identify species?

(Q4) Which approaches and methods do they consider most suitable when investigating species at school?

Methods

Data collection

The present study took place at one university in the federal state of Baden-Württemberg, which places much emphasis on biodiversity education. Data were collected with the help of a PowerPoint presentation and a questionnaire. All data collection exercises took place during normal lesson hours of biology courses and required approximately 45 minutes. Lecturers were contacted in advance and asked for their support. Student teachers were not informed in advance about the study. At the start of each data collection exercise, a short introduction about the PowerPoint presentation and the questionnaire was provided, always by the same person and in a similar way. At the end, all participants received some sweets to thank them for their participation. Participation was voluntary and anonymity guaranteed to the participants. A pilot test was made with student teachers enrolled in an ecology course, who did not participate in the present study. No changes to the questionnaire were needed.

PowerPoint presentation and questionnaire

Overall, 18 plant species and 18 animal species were presented to the study participants (Table 1). The species were included in two separate PowerPoint presentations, i.e. one presentation for plants and one for animals. Each presentation was shown to about 180 student teachers and the subsequent questionnaire items referred either to plants or to animals. All species were shown as photographs, in colour and at high resolution. Typical features of the species were clearly visible. Each species was presented for 30 seconds. After all species had been shown, the presentation started again.

Species selection followed a range of criteria. Species had to be (1) typical for Germany, (2) presented in species-identification courses at the target university, (3) characterised by typical features, (4) already been used in other species identification tests, and (5) from different taxonomic orders and functional groups (e.g. trees and herbs; mammals and insects).

Table 1. *Plant and animal species student teachers had to identify in a PowerPoint presentation. Brackets indicate that names at the genus or species level were accepted as correct.*

Plant species		Animal species	
Common name	**Scientific name**	**Common name**	**Scientific name**
Silver birch	*Betula pendula*	(European) badger	*Meles meles*
Large-leaved lime	*Tilia platyphyllos*	(Red) fox	*Vulpes vulpes*
Creeping buttercup	*Ranunculus repens*	Fat dormouse	*Glis glis*
Shepherd's-purse	*Capsella bursa-pastoris*	Barn swallow	*Hirundo rustica*
White campion	*Silene latifolia*	Great tit	*Parus major*
Greater plantain	*Plantago major*	Laughing gull	*Larus ridibundus*
Wild strawberry	*Fragaria vesca*	Great spotted woodpecker	*Dendrocopus major*
Meadow geranium	*Geranium pratense*	Brown trout	*Salmo trutta f. fario*
Common poppy	*Papaver rhoeas*	(Northern) pike	*Esox lucius*
Red dead-nettle	*Lamium purpureum*	Common viper	*Vipera berus*
White clover	*Trifolium repens*	Slow worm	*Anguis fragilis*
Red Clover	*Trifolium pratense*	Fire salamander	*Salamandra salamandra*
Cornflower	*Centaurea cyanus*	Common toad	*Bufo bufo*
Wild chamomile	*Matricaria chamomilla*	European cockchafer	*Melolontha melolontha*
Canada thistle	*Cirsium arvense*	Colorado beetle	*Leptinotarsa decemlineata*
(Common) yarrow	*Achillea millefolium*	Red wood ant	*Formica rufa*
(Common) dandelion	*Taraxacum officinale*	Peacock butterfly	*Inachis io*
Orchard grass	*Dactylis glomerata*	Brown-lipped snail	*Cepaea nemoralis*

The questionnaire consisted of four parts (covering research questions Q1-Q4). The first part investigated participants' familiarity with the species presented, and features used to identify plants or animals (see Q1). Participants were asked to write down, as precisely as possible, the names of the plants/animals presented. An answer was considered correct if the common name of a species, or its scientific name, was provided (see Table 1). In a multiple-choice question, participants were also asked to indicate the three most important features they had used when identifying the plant/animal species presented. In a similar way, they were asked which features they would use when identifying species in nature (list of features in Table 2).

The second part of the questionnaire investigated participants' taxonomic interest and sources of knowledge about species (see Q2). Participants were asked to indicate their interest in identifying plants/animals on five-step

scales, ranging from 1: very low to 5: very high. They were then asked to indicate their sources of knowledge about plants/animals (see answer options in Table 3). If participants had indicated the university as a source, they were asked to specify their answer by ticking one or more of the following options: lecturer, teaching material, excursions, indoor courses, and to explain their choices. Because experiences in school and knowledge of local organisms were found to be predictors for student teachers' readiness to implement species investigations later in school (Brewer, 2002; Lindemann-Matthies et al., 2011), participants were also asked to indicate how often they had identified plants/animals during their own schooldays (on five-step scales, ranging from 1: very rarely to 5: very often), and where they had done so (primary school, lower or upper secondary school).

The third part of the questionnaire investigated participants' satisfaction with their teacher preparation and self-estimated competence to identify species (see Q3). Participants were asked whether they had attended courses in plant/animal identification. They were then asked how satisfied they felt with the amount of information provided (on five-step scales, ranging from 1: very unsatisfied to 5: very satisfied). They were also asked whether they felt sufficiently prepared to implement species identification activities in school and, if not, to write down ideas for improvement. Because perceived competence is a significant determinant of a person's intrinsic motivation and actual competence to carry out future tasks (Bandura & Schunk, 1981; Losier & Vallerand, 1994), participants were further asked to estimate their competence in identifying plants/animals on five-step scales, ranging from 1: very incompetent to 5: very competent.

The fourth part of the questionnaire investigated which approaches and methods participants considered important when investigating species at school (see Q4). For both indoor and outdoor investigations, participants had to choose the three most suitable approaches (see Table 4) to rank-order them by priority and to explain their first priority. Participants were also asked to indicate the three most suitable teaching materials when identifying species in class (living plants/living animals, dried plants/stuffed animals, drawings, pictures, photographs, books, magazines, CD/DVDs, internet) and to rank-order them by priority.

Participants and data analysis

Overall, 357 student teachers participated in the study. They either filled-in the questionnaire about plants (183 persons) or the one about animals (174

persons). About 60% of participants were in primary and 40% in secondary teacher training, and 88% were women. This reflects the typical ratio at the target university. Participants were, on average, in their third year of study (mean number of terms = 4.8, SD = 2.0).

General linear models (Type II SS) were used to test for influences on participants' taxonomic knowledge (number of plant/animal species correctly identified). As this type of analysis does not allow strong correlations between explanatory variables, Pearson correlations between the explanatory variables were tested first. Self-estimated competence to identify plants/animals was strongly correlated with interest in identifying plants/animals (all $p < 0.001$). Moreover, the probability that participants had already taken species identification courses strongly increased with their length of study ($p < 0.001$). The following factors and variables were initially included in the models: sex (0: male, 1: female), amount of time spent on species identification during schooldays (scale from 1–5), study orientation (0: primary school, 1: secondary school), participation in species identification courses during teacher training (0: no, 1: yes), satisfaction with the courses offered on species identification (scale from 1–5), interest in identifying plants/animals (scale from 1–5). The final minimum adequate models were obtained by backward elimination of non-significant variables (Crawley, 2005). All analyses were carried out with IBM SPSS Statistics for Windows, version 22.

Results

(Q1) Knowledge of local plants and animals, and features used to identify species

On average, participants could correctly identify 23% of the plant species and 44% of the animal species shown to them in the PowerPoint presentation (meanplants = 4.1 ± 0.21 and meananimals = 8.0 ± 0.26 out of 18, respectively). Common dandelion (Taraxacum officinale), common poppy (Papaver rhoeas) and wild strawberry (Fragaria vesca) were the best-known plant species (Figure 1a), while red fox (Vulpes vulpes), European badger (Meles meles) and European cockchafer (Melolontha melolontha) were the best-known animal species (Figure 1b).

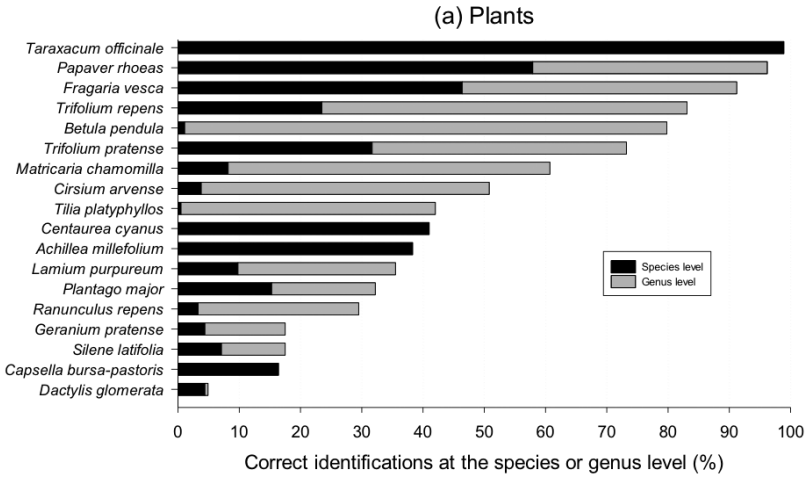

Figure 1a. Proportion of student teachers (n = 183) who correctly identified plants at the species or genus level. The species were shown in a PowerPoint presentation.

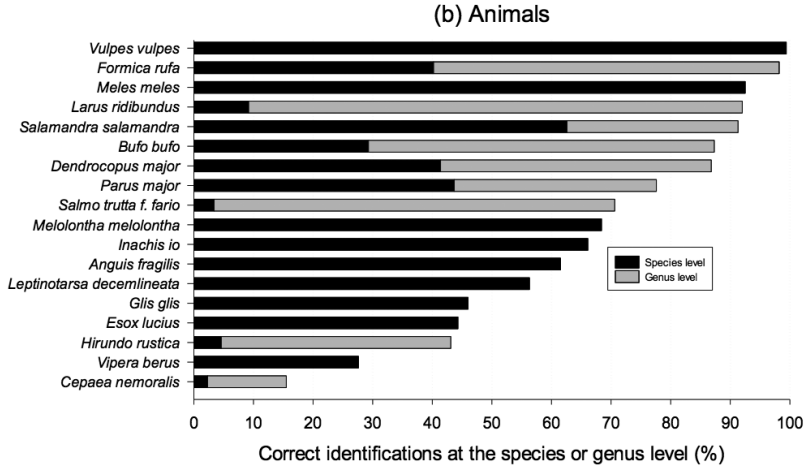

Figure 1b. Proportion of student teachers (n = 174) who could correctly identify animals at the species or genus level. The species were shown in a PowerPoint presentation.

About 49% of participants had already taken courses in species identification. Participants, who had taken such courses, identified more species correctly than those who had not (plants: 5.6 ± 0.27 vs. 2.8 ± 0.27, respectively, $F_{1,181} = 54.14$, $p < 0.001$; animals: 9.4 ± 0.33 vs. 6.7 ± 0.32, respectively, $F_{1,169} = 35.84$, $p < 0.001$).

In the PowerPoint presentation, participants identified plants mainly by their flowers, whereas they stated that in nature, they would identify plants mainly by leaves (Table 2a). With regard to animals, participants identified (or would identify) them largely by shape and colour (Table 2b).

(Q2) Interest in identifying species and sources of knowledge

Participants were only moderately interested in identifying plants (mean score of 3.0 ± 0.07 on the five-step scale), but they were rather interested in identifying animals (mean score of 3.7 ± 0.05). Whether they had already attended courses in species identification did not influence the results (both $p > 0.210$).

Family and school were major sources of participants' knowledge of species (Table 3). If their knowledge of plants was primarily due to university education, it was mainly acquired through excursions and species identification courses (indicated by 37% of participants each), lecturers (30%) and teaching material (24%). Similarly, knowledge of animals was mainly acquired through excursions and teaching material (indicated by 32% of participants each). Lecturers (23%) and species identification courses (13%) were indicated less often.

Table 2. *Features used when identifying (a) plant species and (b) animal species in a PowerPointpresentation and in nature. In a multiple-choice question, student teachers were asked to indicate the three features they considered to be most important. For each feature, the proportion of student teachers who indicated it as one of their three choices is given in the table.*

(a) Plant species		
Feature	PowerPoint (n=160)	Nature (n=148)
	Response (%)	Response (%)
Flower	93.1	62.8
Leaves	70.0	90.5
Colour	64.4	14.9
Shape	50.6	0.0
Size	11.2	44.6
Habitat	5.6	66.2
Seeds	2.5	6.1
Smell	not asked	10.8
Taste	not asked	0.7

(b) Animal species		
Feature	PowerPoint (n=156)	Nature (n=154)
	Response (%)	Response (%)
Colour	95.5	71.4
Shape	91.7	86.4
Size	67.9	49.4
Habitat	39.7	51.9
Sound	not asked	25.3
Movement	not asked	12.3
Smell	not asked	0.6
Touch	not asked	1.3

Table 3. *Sources of knowledge about (a) plants and (b) animals. In a multiple-choice question, student teachers were asked to indicate those three sources they considered to be most important. For each source, the proportion of student teachers who indicated it as one of their three choices is given in the table.*

Source	(a) Plants (n=129)	(b) Animals (n=143)
	Response (%)	Response (%)
Family	80.6	69.1
School	72.9	68.5
University	68.2	57.3
Media	49.6	65.7
Hobby	19.4	27.3
Friends	9.3	8.4

Participants stated that they had rarely identified plants or animals during their own schooldays (plants: mean score of 1.7 ± 0.06 on the five-step scale; animals: mean score of 1.9 ± 0.07). If they had identified species, this took place in primary school (indicated by 44% of participants for plants and by 48% for animals) as well as in lower (50% and 51%) and upper secondary school (12% and 15%).

(Q3) Satisfaction with teacher preparation and competence to identify species

Participants were moderately satisfied with the number of courses offered (plants: mean score of 3.3 ± 0.06 on the five-step scale; animals: mean score of 3.1 ± 0.07, respectively). About 54% of participants felt that they needed more knowledge and skills to identify plants later in school, and 64% felt so for animals. In both cases, ideas for improvement were more time, practical work, and excursions.

Participants who had already attended courses in species identification felt more satisfied with the courses offered than those who had not (plants: mean scores of 3.5 vs. 3.0 on the 5-step scale, $F_{1,143} = 17.67$, $p < 0.001$; animals: mean scores of 2.9 vs. 3.2, $F_{1,138} = 5.35$, $p = 0.022$).

Participants felt barely competent to identify species (plants: mean score of 2.4 ± 0.07 on the 5-step scale; animals: mean score of 2.8 ± 0.07). However, there was a clear positive correlation between the number of species participants could correctly identify in the PowerPoint presentation and their perceived competence (plants: $r = 0.55$, $n = 177$, $p < 0.001$; animals: $r = 0.45$, $n = 166$, $p < 0.001$). Moreover, the more often participants had identified organisms

during their own schooldays, the more competent they felt (plants: $r = 0.19$, $n = 177$, $p = 0.015$; animals: $r = 0.24$, $n = 166$, $p = 0.002$).

The number of correctly identified plants increased with interest in identifying plants (GLM, $F_{1,131} = 8.22$, $p = 0.005$) and participation in species identification courses ($F_{1,131} = 42.11$, $p < 0.001$). Likewise, the number of correctly identified animals increased with interest in identifying animals ($F_{1,129} = 13.91$, $p < 0.001$) and participation in species identification courses ($F_{1,129} = 30.15$, $p < 0.001$).

(Q4) Successful approaches and methods for species investigations

Participants considered learner-centred education and experience-based learning to be most important when identifying plants and animals in school (Table 4). This was the case for both indoor and outdoor education. According to the participants, a learner-centred approach has a strong positive effect on learning, fosters interest and motivation, and allows pupils to be active and creative. There was hardly any difference in participants' reasoning with regard to plants or animals. Participants argued, for instance, that 'learner-centred education follows a constructivist approach, in which the learner, and not the teacher, decides what and how to learn'. Other participants felt that 'people learn most by self-guided learning' and that 'typical features of organisms will be memorised best with learner-centred approaches'. One participant pointed out that a learner-centred approach 'is fun and allows pupils to detect and develop their own skills'.

With regard to experience-based learning, participants argued, for instance, that 'pupils have to experience organisms with all senses; otherwise, they will not remember them' and that 'with their own experiences, pupils will remember organisms best'.

Living plants and animals were considered most important when identifying organisms at school (chosen by 94.8% and 75.7% of participants, respectively, as their first priority). Dried plants were chosen by 2.6% and stuffed animals by 10.5% of participants as their first priority. Photographs were prioritised by 0.6% of participants for plants, and by 7.9% for animals. Books, magazines or CD/DVDs were prioritised by 2.0% for plants and by 5.9% for animals.

Table 4. *Approaches used when investigating (a) plant species and (b) animal species in the classroom and outdoors. In a multiple-choice question, student teachers were asked to indicate the three approaches they considered most suitable. For each approach, the proportion of student teachers who indicated it as one of their three choices is given in the table.*

Approach	(a) Plant species		(b) Animal species	
	Indoor (n=150)	Outdoor (n=140)	Indoor (n=144)	Outdoor (n=136)
	Response (%)	Response (%)	Response (%)	Response (%)
Student-centred	89.3	95.0	86.8	94.1
Experience-based	52.7	67.1	49.3	65.4
Project work	43.3	44.3	45.8	44.1
Cooperative learning	37.3	28.6	39.6	27.9
Experiments	34.7	28.6	36.1	29.4
Teacher-centred	22.7	17.1	20.1	16.9
Problem-based	10.7	10.7	14.6	14.0
Group work	9.3	8.6	7.6	8.1

Discussion

Without special training at university, student teachers could only correctly identify three out of 18 plants and seven out of 18 animals that were shown to them in a PowerPoint presentation. After university training, participants could identify two more plant and three more animal species. University training thus had a positive effect on participants' taxonomic knowledge, which has also been found in other studies (Taraban, McKenney, Peffley & Applegarth, 2004; Wyner & Berkov, 2012). However, the small effect of university training indicates a strong need to improve the training of biology undergraduates so that they can start training the coming generations (see also Leather & Quicke 2009).

Participants identified more animal than plant species correctly, most likely due to their greater interest in identifying animals. This reflects the general tendency that children and adults are more interested in animals than plants (Flannery, 1991; Palmberg et al., 2015; Wandersee, 1986; Wandersee & Schussler, 1999) and are also more informed about animals (Hershey, 1996; Lindemann-Matthies, 2002a). Charismatic mammals, such as red fox and European badger, were correctly identified by almost all participants (as in Eschenhagen, 1982). Common and colourful plants, such as dandelion and poppy, were the best-known plant species, which was also the case when pupils were asked to name wildflowers of Germany (Hesse, 1984) and Switzerland (Lindemann-Matthies,

2002a). Inconspicuous plant species such as shepherd's-purse and greater plantain, in contrast, were among the least identified species, although the previous was shown with its characteristic fruits. Similar results were found in children, adolescents and teachers when pictures of these plants were presented (Lückmann & Menzel, 2014; Scherf, 1988). During a field course in the UK, hardly one in 20 biology students recognised a plantain as such (Leather & Quicke, 2010).

Study participants identified animals mainly by shape and colour. This was also the case in a Nordic-Baltic research project, in which almost 90% of student teachers used shape and colour when identifying animals (Palmberg et al., 2015). That colour is an important animal determination criterion, and that colour picture keys may be more effective than mere language ones has been confirmed (Randler, 2008). Striking features such as colour, shape and size were also found to be important when children classified animals (Tunnicliffe & Reiss, 1999). As in the present study, the habitat in which an organism occurs was of only minor interest, indicating that organisms are recognised more as isolated entities than as integral parts of an environment (Tunnicliffe & Reiss, 1999, 2000; Palmberg et al., 2015). When identifying plants, participants focused primarily on flower characteristics, i.e. the primary feature for identifying whole plant families (Eberbach & Crowley, 2009). In nature, however, participants would clearly prioritise leaves, most likely due to their realisation that flowers are simply not present over long periods of the year or, as in many tree species, too high-up. In contrast to other studies with children and student teachers (Kos & Jerman, 2015; Palmberg et al., 2015), the colour of a flower was only a minor identification criterion for our participants, especially when identifying organisms in nature. This is an interesting result as many easy-to-handle field guides use flower colour as a first identification step.

The family was the most important source of knowledge about plants and animals (as in Scherf, 1988; Tunnicliffe & Reiss, 1999, 2000). In contrast to other studies (Palmberg et al., 2015; Patrick & Tunnicliffe, 2011; Patrick et al., 2013), school education was almost equally important, although participants had rarely identified plants or animals during their own primary or secondary education. However, the more often participants had practiced species identification at school, the more competent they felt in this regard (as in Lindemann-Matthies et al., 2011). Such activities in schools have become rare. Therefore, teacher education has to compensate for the lack of taxonomic experience, if we want teachers who can support their pupils in developing an empathetic perspective towards biodiversity. Our study shows that experiences with species identification during teacher education indeed contributed to student teachers'

competence and thus to intrinsic motivation to engage their future pupils in such activities (see Bandura & Schunk, 1981).

Species-identification activities in school, which allow pupils to be active and gather practical skills, were clearly prioritised over teacher-centred ones. Moreover, the use of living organisms was clearly preferred over other methods (as in Palmberg et al., 2015). Living organisms in species identification courses and the active involvement of learners were found to be rather effective (e.g. Scott et al., 2012; Taraban et al., 2004). University students learned more when exposed to living instead of web-based material (Taraban et al., 2004) and were also better able to sort, group and describe living organisms which they had collected themselves (Scott et al., 2012). Among secondary pupils, hands-on, group-based and learner-centred work lead to higher post-test retention rates than teacher-centred education does (Randler & Bogner, 2002).

Caution should be exercised in generalising the results of this study, as our data are based on a survey of only about 350 student teachers from one university. Moreover, two-dimensional pictures of plants and animals, although some close-up pictures of identifiable features were integrated in the presentation, may not be as good for identification purposes as their three-dimensional originals are. A comparison with findings from other studies, where living plants or animals were presented, should thus be taken with care.

Conclusions

Species identification is not an end in itself, but central for understanding ecological concepts, nature and our place in it (Bebbington, 2005; Bilton, 2014; Leather & Quicke, 2009). Moreover, species identification is at the very foundation of biodiversity conservation (Pfeiffer, Scheiter, Kühl & Gemballa, 2011; Randler, 2008; Scott et al., 2012). Nowadays, species identification can be done in rather enjoyable ways, contradicting the perception of boring 'flower-pressing or bug-collecting' activities (Leather & Quicke, 2010). Videos and apps for mobile devices (e.g. Kumar et al., 2012; Pfeiffer et al., 2011) or so-called BioBlitz activities, i.e. the 24-hour intensive cataloguing of diversity at one site might trigger the interest of pupils (Pollock et al., 2015).

The present results demonstrate the crucial role of the initial teacher preparation system in familiarising graduate students with local organisms, and with suitable approaches on how to carry out species identification later on in school. In times of decreasing taxonomic knowledge, but ever increasing loss of biodiversity, this is especially important. We should not end-up with teachers who are no longer able to familiarise their pupils with species, i.e. a core

content of biology education in school. Qualified teachers should at least be familiar with common wild plants and animals in their neighbourhood, in order to understand and teach the very nature of biodiversity. This requires a stronger emphasis on biodiversity and taxonomy in the teacher-training curriculum.

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Scientific Conceptions of Photosynthesis among Primary School Pupils and Student Teachers of Biology

Darja Skribe Dimec[1] and Jelka Strgar*[2]

Photosynthesis is the most important biochemical process on Earth. Most living beings depend on it directly or indirectly. Knowledge about photosynthesis enables us to understand how the world functions as an ecosystem and how photosynthesis acts as a bridge between the non-living and living worlds. It is, therefore, understandable that photosynthesis is included in national curricula around the world. The practice unfortunately shows that students at all school levels mostly learn about photosynthesis by rote. Consequently, they have difficulties understanding this vital process. Research also shows many misconceptions in relation to photosynthesis among students of different ages. Based on these, the main aim of our study was to explore the scientific conceptions about photosynthesis held by primary school pupils and student teachers of biology. Data were collected using a questionnaire containing seven biology content questions. The sample consisted of 634 participants, 427 primary school pupils (aged 11–14), and 207 student teachers of biology (aged 20–23). We found that the populations of primary school pupils and student teachers of biology differ greatly concerning scientific conceptions of photosynthesis. The student teachers showed good and complex understanding of photosynthesis, while pupils showed some misconceptions (location of chlorophyll and photosynthesis in a plant, transformation of energy in photosynthesis). Analysis of the development of scientific conceptions about photosynthesis with age showed that there is very little progress among primary school pupils and none among biology student teachers. More involvement of student teachers of biology in practical work at primary schools during their study was suggested to make student teachers aware of, and better understand pupils' misconceptions.

Keywords: photosynthesis; biology; scientific conceptions; development; primary school; pupils; student teachers of biology

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Znanstvena pojmovanja o fotosintezi pri učencih osnovne šole in bodočih učiteljih biologije

Darja Skribe Dimec in Jelka Strgar

Fotosinteza je najpomembnejši biokemični proces na Zemlji. Od nje je posredno ali neposredno odvisna večina živih bitij na Zemlji. Poznavanje fotosinteze nam omogoča, da razumemo, kako deluje svet kot ekosistem ter kako fotosinteza deluje kot most med neživim in živim svetom. Zato je razumljivo, da je fotosinteza vključena v nacionalne učne načrte široko po svetu. Praksa žal kaže, da se učenci na vseh stopnjah izobraževanja fotosintezo večinoma učijo na pamet. Posledica tega je, da imajo težave pri razumevanju tega pomembnega procesa in da ne morejo uporabljati pridobljenega znanja. Raziskave kažejo tudi številna napačna pojmovanja, povezana s fotosintezo, ki jih imajo učenci različnih starosti. Izhajajoč iz tega, je bil glavni cilj naše študije raziskati znanstvena pojmovanja o fotosintezi med učenci osnovne šole in bodočimi učitelji biologije. Podatke smo zbrali z vprašalnikom, ki je vseboval 7 vprašanj. Vzorec je sestavljalo 634 sodelujočih, 427 učencev osnovne šole (starih 11–14 let) in 207 bodočih učiteljev biologije (20–23 let). Ugotovili smo, da se populaciji osnovnošolcev in bodočih učiteljev biologije med seboj zelo razlikujeta glede znanstvenih pojmovanj o fotosintezi. Bodoči učitelji biologije so pokazali zadovoljivo in kompleksno razumevanje znanstvenih pojmovanj o fotosintezi, medtem ko smo pri osnovnošolcih našli nekatera napačna pojmovanja (lega klorofila in poteka fotosinteze v rastlini, energetske pretvorbe pri fotosintezi). Analiza razvoja znanstvenih pojmovanj o fotosintezi glede na starost sodelujočih je pokazala, da je napredka na osnovnošolski stopnji zelo malo, med bodočimi učitelji biologije pa ga sploh ni. Predlagali smo večjo vključenost bodočih učiteljev biologije v praktično delo na osnovnih šolah med izobraževanjem na fakulteti, kar bi prispevalo k zavedanju in boljšemu razumevanju napačnih pojmovanj, ki jih imajo osnovnošolci.

Ključne besede: fotosinteza, biologija, znanstvena pojmovanja, razvoj, osnovna šola, učenci, bodoči učitelji biologije

Introduction

Knowledge and understanding of basic concepts related to photosynthesis

If you asked biologists what the basic process on Earth is, they would most certainly respond 'photosynthesis'. Moreover, all non-biologists should respond in kind, since life on Earth depends primarily on this process. Most living organisms, including people, depend on photosynthesis. According to currently available data, the only exceptions are organisms that live in the deep ocean trenches and some other extreme environments; their mode of survival depends on chemosynthesis. As stated by Arnon (in Barker & Carr, 1989a), photosynthesis eminently merits its distinction as the most important biochemical process on Earth. Marmaroti and Galanopoulou (2006) summarised the work of many researchers saying that knowledge of photosynthesis is imperative for a basic understanding of how the world functions as an ecosystem and how it acts as a bridge between the non-living and living worlds.

Consequently, it is understandable that learning about the process of photosynthesis is included in national school curricula. The international comparative study Trends in International Mathematics and Science Study (TIMSS) always includes items related to photosynthesis, which confirms the importance of this topic in the compulsory learning content of schools. In the national standards in the US, photosynthesis is included in the category 'matter cycling and energy transfer in natural ecosystems' (National Research Council, 1996). The latest science standards include photosynthesis within the disciplinary core ideas in the unit Organisation for Matter and Energy Flow in Organisms: 'Construct a scientific explanation based on evidence of the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms' (MS-LS1-6. Next Generation Science Standards, 2013).

Slovenian curriculum and biology education

In Slovenia, per the school curriculum, pupils begin to familiarise themselves with the foundations of photosynthesis in the second grade of primary school, when aged seven years. The learning objective is to 'demonstrate that plants need air, water with mineral substances, and light in order to live' (Kolar, Krnel & Velkavrh, 2011, 11). In the third grade, the general learning objective is that pupils learn 'that living organisms receive something from the environment (food, air, water) which is processed and transmitted into the

environment'. The learning objective which refers only to the plants is that pupils 'are able to justify why plants more than other living organisms need light and water with mineral substances' (Kolar et al., 2011, p. 11). An objective in the fourth grade is only indirectly related to photosynthesis. Pupils have to classify living things into groups according to common characteristics (Vodopivec, Papotnik, Gostinčar Blagotinšek, Skribe Dimec & Balon, 2011, p. 17). The learning objectives related to photosynthesis of the curriculum for fifth grade are: 'The pupil is able to explain that plants from water and carbon dioxide produce food (organic matter) and excrete oxygen, and that, for this process (photosynthesis) sunlight as an energy source and chlorophyll are needed,' and 'the pupil is able to explain that the plants are producers and animals are consumers (of organic matter)' (Vodopivec et al., 2011, pp. 17–18). In sixth grade, the focus is on plant issues, and an entire chapter is devoted to photosynthesis (and cell respiration) in which the pupils' knowledge from previous classes is upgraded and expanded (Skvarč et al., 2011). In the seventh grade, there is an emphasis on learning about bacteria, fungi, and animals (Skvarč et al., 2011). In the final, ninth grade of primary school, the learning objective connected with photosynthesis has one objective ('[...] photosynthetic cyanobacteria have started to produce oxygen as a by-product of photosynthesis [...]' Vilhar et al., 2011, p. 17). We can conclude that photosynthesis is a process dealt with throughout the primary school curriculum, with the most emphasis in the sixth grade.

Research studies about conceptions of photosynthesis

Since the 1990s, when the constructivist theory of learning and teaching was implemented in education, many researchers have focused on students' conceptual development and cognitive processes. Deshmukh (2015) states that all these studies accepted that each student had a different cognitive structure because of their different abilities, backgrounds, attitudes, and experiences. Moreover, that this leads to intuitive understanding, which often means that something a person knows and believes does not match what is known to be scientifically correct. The constructivist theory established the term 'misconception' in pedagogy. Misconceptions (a.k.a. 'alternative conceptions', 'alternative frameworks', etc.) are a key issue of constructivism in science education, and a major theoretical perspective informing science teaching (Taber, 2011). Ozmen (in Deshmukh, 2015, p. 32) pointed out that 'a student's misconceptions before or after formal instruction have become a major concern among researchers in science education because they influence how students learn new scientific knowledge, play an essential role in subsequent learning, and become a hindrance in acquiring

the correct body of knowledge.' Deshmukh (2015) refers to a variety of authors and summarises principal sources of students' science misconceptions, including textbooks and reference books, teachers, cultural beliefs and practices, life experiences, anthropomorphism, analogies, intuition, and language.

According to the widespread opinion about the importance of understanding the process of photosynthesis, it is not surprising that many researchers wanted to know what misconceptions students have in connection with this process. Driver et al. (1992) found that children around the world have similar problems in the understanding of complex processes, such as photosynthesis. The universal and very persistent intuitive conception, identified in all studies with subjects of all ages, is that plants get their food from their environment, especially from the soil (Leeds National Curriculum Science Support Project, 1992). Other common misconceptions identified are: roots are the organs of feeding; plants have multiple sources of food; carbon dioxide, water, and minerals are food for plants; sunlight, absorbed by plants, is food; and photosynthesis is something that plants do to the benefit of people and animals, particularly in relation to the exchange of gasses. A comprehensive examination of pupil understanding of photosynthesis was made by Marmaroti and Galanopoulou (2006). In their study, they examined six aspects of photosynthesis: physiology, photosynthesis and energy, photosynthesis as a chemical reaction, photosynthesis and plant feeding (autotrophy), photosynthesis and respiration, and photosynthesis and the function of the ecosystem. Their conclusions were that pupils do not understand energy transformations and the role of chlorophyll in photosynthesis; they do not see photosynthesis as a chemical reaction; they think plants receive food from their environment, and are confused about photosynthesis and respiration.

Aims of the study and research questions

The main aim of our study was to explore scientific conceptions about photosynthesis held by pupils and student teachers of biology (STB) because of the significance of photosynthesis for the functioning of ecosystems, and its role in the scientific literacy of all people. The aim was to analyse the quality of scientific conceptions about photosynthesis, the complexity of understanding of scientific conceptions about photosynthesis and how these conceptions about photosynthesis are changing with age.

According to our aims, we set the following three research questions:

1. What is the quality of scientific conceptions about photosynthesis held by pupils and student teachers of biology?

2. How complex is the understanding of scientific conceptions about photosynthesis held by pupils and student teachers of biology?
3. How do scientific conceptions about photosynthesis held by pupils and student teachers of biology change with age?

Methods

In this study, we used a quantitative research approach. Data were gathered in 2014, 2015, and 2016, mostly as part of several graduate theses of students at the Faculty of Education of the University of Ljubljana; however, we used a different methodology of data analysis in the present study.

Sample

The study included 634 participants, of which 427 (67.4%) were primary school pupils (PS) and 207 (32.6%) students of the University of Ljubljana Faculty of Education, future two-subject teachers of biology and chemistry or home economics (STB), who will be teaching biology on the upper primary school level or in secondary schools. The proportion of females (47.8%) among primary school pupils was roughly the same as the proportion of males (52.2%). The teacher population in Slovenia is heavily dominated by females, which is also reflected in our sample, in which females represent 90.4%. For STB, we included participants of the 2nd, 3rd, 4th, and 5th years of study at the university. The sample of primary school pupils consisted of pupils in Grades 6 to 9 (Table 1).

Table 1. *Distribution of participants according to years of education in each educational program (primary school pupils = PS, student teachers of biology = STB)*

Years of education	Typical age	Participants	
		N	f (%)
PS 6	11	103	24.1
PS 7	12	111	26.0
PS 8	13	115	26.9
PS 9	14	98	23.0
STB 2	20	77	37.2
STB 3	21	28	13.5
STB 4	22	69	33.3
STB 5	23	33	15.9
Σ		634	100.0

Questionnaire

Data were collected via a questionnaire containing three demographic questions (educational program, gender, and year of education) and seven multiple choice questions. Participants had to choose one answer from out of three to five. The same or similar questions were used in surveys by Domingos-Grilo, Reis-Grilo, Ruiz and Mellado (2012; question 'The main purpose of photosynthesis is to ...'), Marmaroti and Galanopoulou (2006; questions 'Which pair of substances are the reactants in photosynthesis?', 'Which substances are products of photosynthesis?', 'Which part of the plant contains chlorophyll?', and 'In which part of the plant does photosynthesis take place?'), and Çepni, Taş and Köse (2006; 'Into what type of energy do plants transform sunlight into energy?'). We also added our own question: 'What type of energy do plants receive from the sun?'

With these questions, we evaluated the following four conceptions in connection with photosynthesis:

1. the function of photosynthesis (question 'The main purpose of photosynthesis is to ...'),
2. the process of photosynthesis (questions 'Which pair of substances are the reactants in photosynthesis?', 'Which substances are products of photosynthesis?'),
3. photosynthesis and energy (questions 'What type of energy do plants receive from the sun?', 'Into what type of energy do plants transform sunlight into energy?'), and
4. chlorophyll (questions 'Which part of the plant contains chlorophyll?', 'In which part of the plant does photosynthesis take place?').

Statistical analysis

Basic descriptive statistics was performed. Since the data were not normally distributed, the non-parametric Mann-Whitney and Kruskal-Wallis tests were used to determine the statistical significance of differences between the responses of participants in various educational programs, years of education in this program, and gender.

Results

In our study about the scientific conceptions of photosynthesis, we investigated primary school pupils and a population of STB. Mann-Whitney U tests show that to all seven questions concerning scientific conceptions primary school pupils gave statistically significantly different answers compared to STB (all $p < 0.05$), which means that the two populations differed significantly in the scientific conceptions of photosynthesis.

Quality of scientific conceptions about photosynthesis

With the first question, we attempted to determine how pupils and STB understand the function of photosynthesis (Table 2). The most common response of pupils was that the main purpose of photosynthesis is the formation of oxygen (49%), followed by the formation of glucose (38%). Among STB, a sequence of those two responses is reversed. STB believe that the main purpose of photosynthesis is the formation of glucose (63%) and 32% think that the formation of oxygen is the main purpose of photosynthesis. The remaining responses were chosen by less than 9% of the pupils and STB. Participants had to choose only one response from the four offered, and since during the process of photosynthesis two substances are made, the responses were combined (formation of glucose and formation of oxygen). We found that 87% of the pupils and 96% of the STB at least partially know what is made during photosynthesis. In their study, Domingos-Grilo et al. (2012) started from the fact that in the evolution the formation of glucose was the primary purpose of photosynthesis and oxygen was a by-product, so we used the formation of glucose as the correct answer.

Table 2. *Percentage distribution of pupils' and student teachers' of biology (STB) responses to the question 'What is the main purpose of photosynthesis?'*

Response	Pupils (%)	STB (%)
Consumption of carbon dioxide	8.6	4.0
Consumption of water	4.7	0.5
Formation of glucose	37.7	63.2
Formation of oxygen	49.0	32.3

The knowledge of the process of photosynthesis was measured with two questions (Table 3). With the first question, we wanted to verify whether the participants are aware of the reactants in photosynthesis, and with the second

question whether they know the products of photosynthesis. When recognising reactants, the most common answer of all participants was the correct one (carbon dioxide and water): pupils (59%) and STB (88%). In the case of pupils, a remarkable proportion were represented by the incorrect replies 'oxygen and water' (22%) and 'carbon dioxide and organic matter' (14%).

Furthermore, in identifying the products of photosynthesis in both groups of participants, the most common answer was the correct one (glucose and oxygen): pupils (61%) and STB (93%). Quite a large proportion of pupils (23%) chose the incorrect answer 'oxygen and water.' Each of the other wrong answers in both questions was chosen by less than 9% of the pupils and STB.

The proportion of pupils' correct answers of reactants and products is quite similar (59% reactants, 61% products). The same also applies to the STB (reactants 88%, products 93%). Both groups of participants know the products of photosynthesis slightly better than they do the reactants.

Table 3. *Percentage distribution of pupils' and student teachers of biology (STB) responses to the questions about the process of photosynthesis*

Which pair of substances are the reactants in photosynthesis?	Pupils (%)	STB (%)	Which substances are products of photosynthesis?	Pupils (%)	STB (%)
Oxygen and organic matter	5.6	1.0	Glucose and oxygen	61.3	92.7
Oxygen and water	21.9	2.9	Oxygen and water	22.7	3.9
Carbon dioxide and organic matter	14.0	7.8	Carbon dioxide and glucose	9.4	3.4
Carbon dioxide and water	58.5	88.2	Carbon dioxide and water	6.7	0.0

To understand the events related to energy during the process of photosynthesis, we used two questions (Table 4). The purpose of the first question was to determine the form of the energy that plants obtain from the sun. The second question asked about into what type of energy plants transform sunlight energy. The dominant response in both the pupils and STB was that the energy that plants get from the sun is in the form of light energy (pupils 74%, STB 89%). In addition, pupils frequently chose the wrong answer, i.e. that the plants receive heat from the sun (23%). The fact that plants receive light energy from the sun was known by most of the pupils and STB. The results showed that almost a quarter of pupils have the misconception that plants receive heat from the sun.

Pupils in approximately the same proportion believe that plants transform sunlight energy into chemical energy (35%) or heat (27%) or light energy (24%) (Table 4). A large majority of STB (89%) thinks that sunlight energy is

transformed into chemical energy during the photosynthesis. The results show that understanding of the energy transformation during the photosynthesis is rather vague among the primary school pupils, because they selected different types of energy. However, there is very little such incorrect assessment on the part of STB. Each of the other wrong answers in both questions was chosen by less than 9% of the pupils and STB.

Table 4. *Percentage distribution of pupils' and student teachers of biology (STB) responses to the questions about photosynthesis and energy*

What type of energy do plants receive from the sun?	Pupils (%)	STB (%)	Into what type of energy do plants transform sunlight energy?	Pupils (%)	STB (%)
Chemical energy	3.4	6.3	Electricity	5.1	0.5
Light energy	73.5	88.9	Physical energy/Movement	8.3	0.5
Heat	23.1	4.8	Chemical energy	35.1	88.6
			Light energy	24.2	3.0
			Heat	27.3	7.4

Next, we investigated whether participants know that photosynthesis takes place only where there is chlorophyll. First, we asked them whether they know in which parts of the plants that photosynthesis takes place, and second, whether they know in which parts of the plants there is chlorophyll (Table 5). For pupils, we found that a similar proportion believes that photosynthesis takes place 'in the leaves' (44%) or 'in the green parts of plants' (40%); 11% of pupils believe that photosynthesis takes place 'in the whole plant'. Most of STB replied that photosynthesis takes place 'in the green parts of plants' (88%); 11% reported that it is carried out 'in the leaves.'

On the question of where the chlorophyll is, half the pupils (50%) responded that the chlorophyll is 'in the green parts of plants,' 33% answered 'in the leaves,' and 12% said that it is 'in the roots' (Table 5). The predominant response among STB is that chlorophyll is 'in the green parts of plants' (93%), only a few STB answered that it is 'in the leaves' (7%). Approximately 10% of the pupils and 5% of the STB knew better in which part of the plant chlorophyll is than they knew where photosynthesis takes place. Each of the remaining responses in both questions was chosen by less than 6% of the pupils and STB.

Table 5. *Percentage distribution of pupils' and student teachers of biology (STB) responses to the questions about chlorophyll*

In which part of the plant does photosynthesis take place?	Pupils (%)	STB (%)	Which part of the plant contains chlorophyll?	Pupils (%)	STB (%)
In the whole plant	11.3	1.0	Whole plant	5.1	0.0
In the roots	2.4	0.0	Roots	12.4	0.0
In the leaves	43.9	11.0	Leaves	32.7	7.4
In the stem	2.7	0.0	Green parts of the plant	49.7	92.6
In the green parts of the plant	39.8	88.0			

Complexity of scientific conceptions about photosynthesis

We explored the complexity of the scientific conceptions of photosynthesis by cross-analysing complementary or logically-related questions. Two questions were related to the process of photosynthesis, two to energy in photosynthesis, and two to chlorophyll.

In order to determine the complexity of understanding the process of photosynthesis, we cross-analysed responses of pupils and STB to the questions 'Which pair of substances are the reactants in photosynthesis?' and 'Which substances are products of photosynthesis?' (Table 6). We found that among pupils and STB the predominant combination was the correct one: the reactants in photosynthesis are carbon dioxide and water, and the products are glucose and oxygen (pupils 41%, STB 84%). Pupils also chose a large proportion of various false combinations. Twelve per cent of pupils chose water instead of glucose as a product of photosynthesis. Nine per cent of the pupils chose the correct products, but incorrect reactants (instead of water they picked organic matter). Eight per cent of the pupils chose a surprising combination in which the reactants are the same as the products. A further eight per cent of the pupils who chose the correct products and false reactants (instead of carbon dioxide water was chosen).

Table 6. *Cross-analysis of pupils' and student teachers of biology (STB) responses to determine the complexity of understanding the process of photosynthesis*

Response	Pupils (%)	STB (%)
Reactants are oxygen and water, and products are glucose in oxygen	7.9	2.0
Reactants are oxygen and water, and products are oxygen and water	8.4	0.0
Reactants are carbon dioxide and organic matter, and products are glucose in oxygen	9.4	6.4
Reactants are carbon dioxide and water, and products are glucose in oxygen	41.2	83.7
Reactants are carbon dioxide and water, and products are oxygen and water	11.5	2.5
Reactants are carbon dioxide and water, and products are carbon dioxide and glucose	3.7	2.0

We also explored the complexity of understanding the connection between photosynthesis and chlorophyll. For this purpose, we cross-analysed responses of pupils and STB to the questions 'Which part of the plant contains chlorophyll?' and 'In which part of the plant does photosynthesis take place?' (Table 7). The most frequent response in both groups was the correct combination: 'Chlorophyll is in the green parts of the plant, and photosynthesis takes place in the green parts of the plant' (pupils 28%, STB 84%). Many pupils answered that chlorophyll is in the leaves (18%) or in the green parts of the plant (17%), or that photosynthesis takes place in the leaves (36%). Ten percent of pupils associated photosynthesis with all green parts of plants, and chlorophyll only with leaves. Even some STB (8%) responded that photosynthesis takes place in leaves, while chlorophyll is in the green parts of the plant.

Table 7. *Cross-analysis of pupils' and student teachers of biology (STB) responses to explore the complexity of understanding the connection between photosynthesis and chlorophyll*

Response	Pupils (%)	STB (%)
Chlorophyll is in the leaves, and photosynthesis takes place in the whole plant	4.1	0.0
Chlorophyll is in the roots, and photosynthesis takes place in the leaves	4.9	0.0
Chlorophyll is in the leaves, and photosynthesis takes place in the leaves	18.3	3.5
Chlorophyll is in the green parts of the plant, and photosynthesis takes place in the leaves	17.3	7.5
Chlorophyll is in the leaves, and photosynthesis takes place in the green parts of the plant	9.8	3.5
Chlorophyll is in green parts of the plant, and photosynthesis takes place in the green parts of the plant	27.9	84.4

The complexity of understanding events related to energy in photosynthesis was examined by cross-analysing the questions 'What type of energy do plants receive from the sun?' and 'Into what type of energy do plants transform sunlight energy?' (Table 8). We found that with pupils and STB the most frequent combination was the correct one: 'Plants receive the light energy from the sun, and transform it into chemical energy' (pupils 29%, STB 79%). Pupils' responses indicate considerable confusion in understanding what is happening with energy in photosynthesis. Most pupils know that plants receive light energy, but a problem occurs with understanding energy transformation in photosynthesis. The same proportion of pupils (17%) answered that light energy is transformed into light energy (thus showing that they do not understand that the process of photosynthesis is about energy transformation), and that light energy is transformed into heat. Most of the other incorrect answers were fairly evenly chosen by both groups, which means that no additional misconceptions were present.

Table 8: *Cross-analysis of pupils' and student teachers of biology (STB) responses to explore the complexity of understanding events related to energy in photosynthesis*

Response	Pupils (%)	STB (%)
Plants receive chemical energy from the sun, and transform it into chemical energy	1.6	5.4
Plants receive light energy from the sun, and transform it into movement	6.0	0.5
Plants receive light energy from the sun, and transform it into chemical energy	29.2	78.7
Plants receive light energy from the sun, and transform it into light energy	16.7	3.0
Plants receive light energy from the sun, and transform it into heat	16.7	6.4
Plants receive heat from the sun, and transform it into chemical energy	4.2	4.5
Plants receive heat from the sun, and transform it into chemical energy	4.2	4.5
Plants receive heat from the sun, and transform it into light energy	6.5	0.0
Plants receive heat from the sun, and transform it into heat	10.2	0.5

Development of scientific conceptions about photosynthesis with age

One of our research questions was to explore the development of pupils' and STB's scientific conceptions of photosynthesis with age. A Kruskal-Wallis H test showed that there was no statistically significant difference between the STB groups in any of the seven questions that tested the scientific conceptions of photosynthesis ($p > 0.05$). However, differences were significant among primary school pupils. We found statistically significant differences in answers

to the items 'Which part of the plant contains chlorophyll?' and 'Which substances are products of photosynthesis?' ($p < 0.05$). There were no significant differences regarding the remaining five items ($p > 0.05$).

Primary school pupils had quite diverse conceptions concerning the question 'Which part of the plant contains chlorophyll?' (Figure 1). In the 6th grade, pupils showed the least developed scientific conceptions of where chlorophyll is in the plant. This is not surprising because it could be that this topic may not yet have been addressed in class when surveyed. In the 7th grade, progress had obviously been made concerning the understanding of this concept; 8th grade pupils again showed less knowledge than 7th grade pupils did. Even at the end of 9th grade understanding where chlorophyll is located in plants is worse than in the 7th grade. Despite the problems primary school pupils had with the location of chlorophyll in plants, all grades predominantly chose the completely correct answer that chlorophyll is in the green parts of plants (40% or more). The sum of correct and partially correct answers show satisfying scientific conceptions (74–90%) in all four grades.

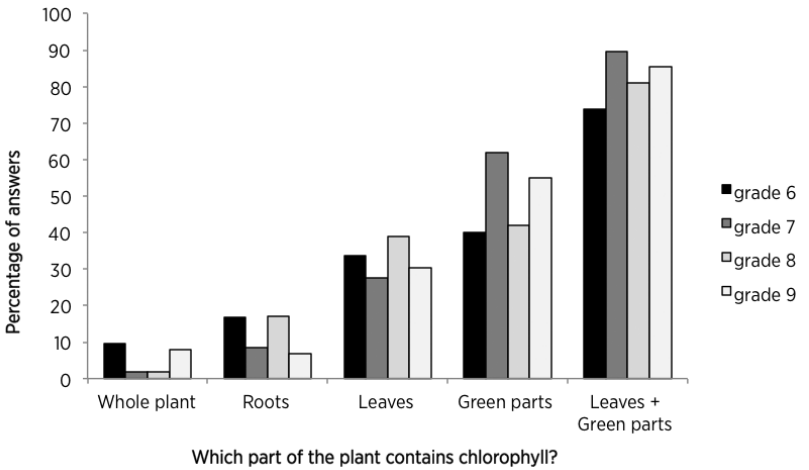

Figure 1. Percentage distribution of pupils' responses to the question 'Which part of the plant contains chlorophyll?' according to different grades.

To the question 'Which substances are products of photosynthesis?', pupils in the 6th grade predominantly chose the correct answer (glucose and oxygen; 49%), and slightly less often the incorrect answer (oxygen and water; 33%). The majority of pupils in the 7th, 8th, and 9th grades chose the correct answer

(63–67%). The second most common response with them was also 'oxygen and water' (18–21%). This comparison leads to the conclusion that 6th-graders possess more misconceptions about the products of photosynthesis than older pupils do. Among pupils in the 7th, 8th, and 9th grades, there is almost no difference in understanding the products of photosynthesis (Figure 2).

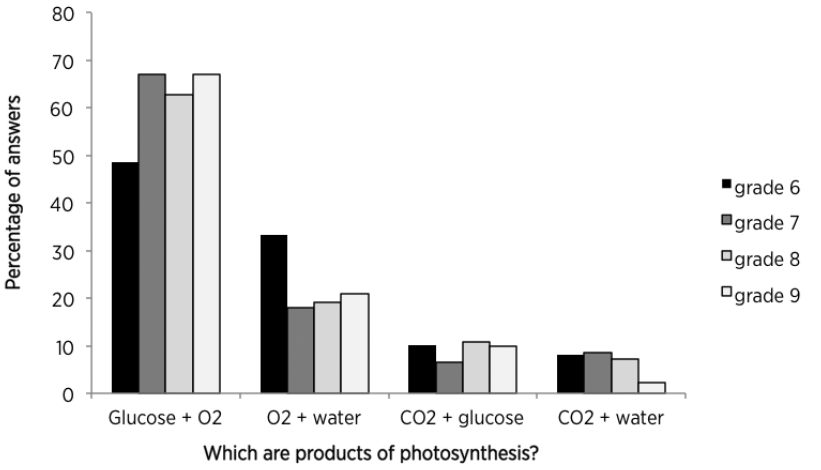

Figure 2. Percentage distribution of pupils' responses of different grades to the question 'Which substances are products of photosynthesis?'

Discussion and conclusions

In our analysis, we found that primary school pupils and STB differ greatly concerning scientific conceptions of photosynthesis.

Our first research question was focused on the quality of scientific conceptions about photosynthesis. An analysis of the quality of scientific conceptions about photosynthesis held by pupils showed that more pupils think that the main function of photosynthesis is the formation of oxygen, and fewer pupils think that the main function of photosynthesis is the formation of glucose. In contrast, the majority of STB see the formation of glucose as the main function of photosynthesis. In fact, it is difficult to define photosynthesis' 'main' function. From the evolutionary point of view, its primary function is the formation of glucose, while oxygen is a by-product. From the perspective of contemporary aerobic organisms, both products are equally important. In connection with the process of photosynthesis, we found that pupils and STB possess good knowledge of the reactants and products. From these results, we

concluded that it is relatively easy to learn the basic equation of photosynthesis, which is not necessarily linked to the understanding of this process. A relatively large proportion of pupils' responses that oxygen and water are needed for photosynthesis could be explained by the fact that many people think that photosynthesis is respiration in plants (Driver et al., 1992). Regarding energy in photosynthesis we found that pupils and STB know very well that plants receive light energy from the sun. In contrast, we found that the transformation of energy in photosynthesis presents a problem for pupils, but not for STB. In addition to the chemical energy pupils frequently answered that energy in photosynthesis is transformed into light and heat. The location of chlorophyll and location of photosynthesis in the green parts of the plants is reasonably well understood by STB. In addition to the green parts of the plants, pupils frequently chose particularly the answer 'in the leaf.' This is probably due to many primary school textbooks, in which the process of photosynthesis is shown simplified in a picture of a plant leaf.

Our second research question was focused on the complexity of understanding of scientific conceptions about photosynthesis. How complex the understanding of scientific conceptions about photosynthesis held by pupils and STB is was explored by cross-analysis. In STB knowledge is very complex, since they showed high response consistency. For pupils, we found quite a few problems. Marmaroti and Galanopoulou (2006) stated that it is easier for pupils to identify products than reactants. We did not come to this conclusion, while almost the same percentage of pupils chose the correct products and false reactants or vice-versa. Noteworthy is the proportion of pupils who associate photosynthesis primarily with leaves, but not with all the green parts of the plant. Pupils demonstrated the highest response inconsistency on the topic of the energy transformation in photosynthesis: for the most part they correctly answered that light energy is necessary for photosynthesis, but were confused about the transformation of this energy. They are not even aware of the energy transformation because they answered that light energy enters and exits the reaction. This was also noted by Marmaroti and Galanopoulou (2006) who stated that this means that they do not understand that photosynthesis is a chemical reaction. In the primary school program, more attention should be given to understanding the transformation of energy. This is a key understanding of the functioning of the ecosystems and thus justifies the claim of Arnon (in Barker & Carr, 1989a) that photosynthesis is the most important biochemical process on Earth.

Our third research question was focused on the development of scientific conceptions about photosynthesis. Analysis of the development of

scientific conceptions about photosynthesis with age showed that there is very little change among primary school pupils and none among STB. There is, however, a large difference between the two groups. As expected, the scientific conceptions of STB are statistically significantly better than those of the pupils. Progress from the 6th to 9th grade in pupils' scientific conceptions was only found concerning the location of chlorophyll and the products of photosynthesis. The most obvious is the progress from 6th to 7th grade, which indicates the realisation of the objectives of the curriculum of the 6th grade.

We are pleased with the fact that STB mastered the basic subject matter of photosynthesis, but we are less satisfied with the knowledge of pupils, especially at the end of the primary education. Many of the latter will never again learn about photosynthesis in their further education. Inadequate pupil knowledge of photosynthesis is perhaps also a consequence of the fact that teachers are not able to properly present this complex topic in class. Perhaps STB lack pedagogical content knowledge. The study by Rode and Skribe-Dimec (2012), which investigated the understanding of photosynthesis, showed that primary school teachers also have many misconceptions about photosynthesis. This would imply that we must ask ourselves which teaching approaches should be used when this topic is presented to pupils in primary school. There is a variety of approaches that can be used in primary schools so that the pupils would be able to understand this crucial process, such as the constructivist approach (Dolenc Orbanić, Skribe Dimec & Cencič, 2016), concept mapping (Novak, 1998; Novak & Gowin, 1984), explicit instruction (Archer & Hughes, 2011), computer-assisted material (Çepni et al., 2006; Keleş & Kefeli, 2010), in-depth analysis of misconceptions (Amir & Tamir, 1994), project-based learning (Holubova, 2008), web-based dynamic assessment (Wang, 2010), conceptual change approach (Yenilmez & Tekkaya, 2006), the 5E Model (Bybee et al., 2006), etc. In addition, an effective strategy for the professional development of science teachers is investigations in which teachers are not consumers of external knowledge, but co-producers and agents of change in the problems that concern them in their classes (Ritchie, 2008). Da Silva, Mellado, Ruiz & Porlán (2007) showed that the decisive moment for teachers to change their way of teaching is to confront them with the misconceptions of their students. Therefore, we believe that prospective teachers should have more direct contact with pupils during their study at the university.

In contrast, the question is also whether this topic might be too complex for 11-year-olds (Grade 6, where the current curriculum places it). Biology teachers and curriculum developers should take into account the fact that photosynthesis is challenging and pupils do not find it interesting. However, they

must understand basic concepts of this process to be able to make informed decisions in life.

Koballa and Glynn (2010) report that a study based on data collected as a part of the TIMSS revealed that attitudes toward science have a strong effect on achievement. They place the importance of attitudes for science learning in the broader context: 'As views of learning become increasingly constructivistic, it is more important than ever, that researchers adopt a comprehensive view of learners that includes affective characteristics' (Koballa & Glynn, 2010, 93), wherein attitudes are part of the affective domain. Therefore, in future studies we need to focus our attention on pupils' attitudes toward photosynthesis and attempt to determine if there is any correlation between scientific conceptions about photosynthesis held by pupils and biology student teachers and their attitudes toward it.

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Biographical note

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Fragmented Knowledge and Missing Connections between Knowledge from Different Hierarchical Organisational Levels of Reproduction among Adolescents and Young Adults

Andrej Šorgo*[1] and Rebeka Šiling[2]

Based on the responses of our sample (N = 310) of adolescents and young adults from Slovenia (students of secondary and tertiary schools, university students) to a number of tasks covering reproduction, from the molecular to organismal levels, it can be concluded that their knowledge is seriously flawed. Correlations of knowledge between individual tasks are low, or even negative, showing patchiness and missed connections between different aspects of reproduction. Our study confirms the well-known difficulties in building a consistent body of knowledge on the genetic–inheritance axis while expanding it to the anatomy and physiology of reproduction. It is crucial to stress the quality of elementary school biology, and science (biology) courses in secondary schools because, for most people, this will be the last formal contact with some important topics that could influence their life decisions.

Keywords: knowledge; biology; misconceptions; genetics; reproduction

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Nepovezanost in manjkajoče povezave med znanjem z različnih hierarhičnih organizacijskih ravni razmnoževanja, ki ga izkazujejo mladostniki in mlajši odrasli

Andrej Šorgo in Rebeka Šiling

Na osnovi odgovorov 310 mladostnikov in mlajših odraslih (dijakov slovenskih srednjih šol, študentov višjih in visokih šol ter univerz) na večje število nalog, povezanih z razmnoževanjem, na ravneh od molekularne do organizemske, lahko ugotovimo, da je njihovo znanje samo pomanjkljivo. Korelacije znanja, izkazanega z odgovori na posamezne naloge, so nizke in včasih celo negativne. Vzorec znanja zaznamuje nepovezanost in manjkajoče povezave med različnimi vidiki razmnoževanja. Z rezultati študije potrjujemo dobro poznane težave v gradnji konsistentnega korpusa znanja na osi genetika – dedovanje ter jo širimo na področji anatomije in fiziologije. Na osnovi pridobljenih spoznanj bi morali nujno pretresti kakovost poučevanja biologije v osnovni šoli in naravoslovja (biologije) v srednjih šolah. Za veliko večino bo namreč takrat pridobljeno znanje zadnji formalni stik s pomembnimi vsebinami, ki lahko zaznamujejo življenjske odločitve.

Ključne besede: znanje, biologija, napačni koncepti, genetika, razmnoževanje

Introduction

Teaching about reproduction is not only one of the traditional biological topics and vital for understanding life phenomena but, especially in the case of human reproduction and sexuality, an important personal and societal issue. Reproduction of organisms and genetics, as underlying principles, are complex issues, which generate the formation of many naïve presentations, alternative concepts or misconceptions, well described by a body of research (Children's ideas, 1992; Nguyen & Rosengren, 2004; Prokop & Fančovičová, 2008; Yip, 1998). Particularly important are misconceptions about human reproduction because these cannot be regarded as merely a biological issue, but also as a cultural and social (societal) issue (Flowers-Coulson, Kushner & Bankowski, 2000; Hamani, Sciaki-Tamir, Deri-Hasid, Miller-Pogrund, Milwidsky & Haimov-Kochman, 2007; Wynn, Foster & Trussell, 2009).

It is possible to identify many causes behind flawed biological knowledge about reproduction and its underlying principles. One of the major reasons is the natural complexity of the issue. Reproduction exists in different forms, from asexual to sexual, and in different combinations of both; it occurs at different hierarchical organisational levels, from subcellular to organismal; inside an individual and between individuals; moreover, as a research topic it is distributed among a number of biological disciplines (De Meeûs, Prugnolle & Agnew, 2007; Folsell & Roughgarden, 2010; Obeso, 2004; Pineda-Krch & Lehtilä, 2004; Tuomi & Vuorisalo, 1989). Not adding to the simplicity is the generation of new knowledge, resulting not only in the addition of details or clarifications to the existing body of knowledge, but also in the generation of new interpretations and concepts (Haque, Gottesman & Wong, 2009; Visscher, Hill & Wray, 2008). Emerging knowledge often challenges both scientific explanations and naïve presentations at all hierarchic levels of reproduction and between them (e.g. Engel Clough & Wood-Robinson, 1985; Mintzes, Trowbridge, Arnaudin & Wandersee, 1991).

The second important cause involves misconceptions presented in study resources (textbooks) used at various educational levels (Aivelo & Uitto, 2015; Castéra, Bruguière & Clément, 2008; Choi & Cho, 1987; Clément & Castéra, 2014; Dos Santos, Joaquim & El-Hani, 2012) and the knowledge and misconceptions held by teachers (Kurt & Ekici, 2013; Veiga, Teixeira, Martins & Meliço-Silvestre, 2006). After didactic transposition (Bosch & Gascón, 2006), teaching resources often present simplified (if not erroneous) diagrams and explanations (Martins, 2010). Furthermore, they do not present a coherent overview of an issue but instead offer a number of contextually varied concepts of the same

artefact or process, sometimes even within the same textbook (Gericke, Hagberg, dos Santos, Joaquim & El-Hani, 2014).

Information obtained from popular commercial textbooks (Smolkin & Donovan, 2015; Schussler, 2008) and other traditional and electronic media and informal sources, such as family, peers, and the common knowledge of a community (Merchant, Brown, Cecil, Grimley & Oh, 2000), probably constitutes the most important source of misconceptions, especially if these are not challenged by formal education.

Aims and purpose of the research

Because reproduction can be regarded as a network of multiple processes rather than a single process occurring at different organisational levels, the aim of the study was to verify the recognition of knowledge levels and the ability to transfer knowledge from one organizational level to another by adolescents and young adults. Through the results of our research, our wish was to identify major flaws in the understanding of reproduction and the misconceptions held by adolescents and young adults at a range of different organizational levels (subcellular, cell, organismal) of reproduction. Our research was exploratory, and no intervention was provided to influence the knowledge and attitudes of the participants, who were secondary and tertiary level students.

Methods

Research design

The research design employs a mixed methodology. After the analysis of elementary and secondary school syllabi and textbooks, a contextual framework about reproduction was assembled. Based on this framework, an initial version of the test was assembled, driven by our wish to assess knowledge both as widely as possible and at different cognitive levels. Consequently, different question formats were used. The initial version was given to a number of university students and university staff for validation. After checking the comments received, an improved version was prepared. Assessment, coding and statistical procedures are presented later in this section and in the results section.

Sample and sampling

The research sample consisted of 315 participants out of 550 persons who received the questionnaire in paper and pencil form. After the exclusion of five questionnaires, 310 (56.4%) completed questionnaires remained. The

questionnaires were administered in the 2010/11 academic year to a number of students from the Universities of Maribor and Ljubljana, as well as general and vocational upper secondary schools. A high number of volunteers (235) failed to return their questionnaire, many of them with the explanation that it was too hard to complete and that they did not want to display their lack of knowledge. Anonymity was guaranteed, and no benefits or penalties were offered to those who participated or rejected participation. The sample characteristics are presented in Table 1.

Table 1. *Sample characteristics (N=310)*

Demographic characteristics	Frequency	%
Gender		
Male	137	44.2
Female	173	55.8
School type		
Professional or vocational secondary school	77	24.8
General upper secondary school (gimnazija)	113	36.5
Secondary school total	**190**	**73**
Higher school	13	4.2
University	107	34.5
Tertiary schools total	**120**	**38.7**
One of the elective Matura subjects was Biology	N = 120	38.7
Yes	34	28.3
No	86	71.7
School Grade in Biology at the end of secondary education*	N = 116	37.4
Sufficient (2)	5	1.6
Good (3)	39	12.6
Very good (4)	46	14.8
Excellent (5)	26	8.4
Total	**116**	**37.4**

*In Slovenian school systems, grades can be understood as follows: (1) insufficient; (2) sufficient; (3) good; (4) very good; and (5) excellent.

Structure of the questionnaire

Reproduction is a complex and varied issue, so our intention was to construct a manageable test dealing with the facts, processes and concepts at different hierarchical organisational levels. Our guiding principle was that the tasks should be doable based on the knowledge acquired by completing compulsory

science and biology curricula in primary and secondary school. Based on these premises, questions and tasks were formed, covering the basic principles of reproduction, with the addition of the demographic part of the questionnaire.

At the broadest levels of knowledge (De Jong & Ferguson-Hessler, 1996), the first content level was the subcellular, with the inclusion of structures and processes such as genes, chromosomes, gene expression, etc. The second was the cellular level, which included processes such as cell division; the third level was anatomical, and the fourth organismal. Overarching concepts (e.g. reproduction, cloning) were also included.

Because of the complexity of the material, varied assessment formats were used, as follows:

a) Open-ended questions were used, when our interest was in recognition of understanding, and to discover alternative concepts.
b) Two-tier diagnostic tests (Lin, 2004; Tsui & Treagust, 2010); the first part offered answers of 'yes', 'no', and 'do not know'. In the second explanatory part, students were asked to explain their decision in open-ended format.
c) Naming of objects and processes in provided sketches of mitotic cell division and a dicot pistil, followed by a number of open-ended explanations.
d) Free-hand drawing (Dikmenli, 2010; Reiss et al., 2002; Sesli & Kara, 2012) of male and female reproductive organs inside a provided outline of the male and female torso, with the additional task of naming the structures.
e) In seeking misconceptions, we provided a number of statements based on previously known misconceptions, with a 'yes', 'no', and 'do not know' response format.

Differing grading schemes were used for knowledge assessment, a feature that can be recognized in the tables in the results section.

Where students were to provide open-ended answers, they received 2 points for correct or almost completely correct answers. As correct answers, we also acknowledge answers that followed textbook explanations, even though it is known that textbook explanations are sometimes oversimplified, if not completely wrong, according to recent knowledge. One point was assigned to a partially correct answer and zero points to an incorrect or missing answer. However, in the tables, incorrect and missing answers are distinguished, because not knowing something is not equal to 'knowing' it incorrectly; however, they were graded with zero points in both cases.

Statistical procedures

Because our interest did not lie in the construction of a new instrument, the basic unit of interpretation comprises individual items (questions, tasks) and not scales. Therefore, reliability statistics, such as Cronbach's alpha are not provided. Because occasional not-normal distribution, frequencies, median, and mode are provided in addition to means and standard deviations as measures of central tendencies. Spearman's rho was the preferred choice for calculating correlations between ordinal data, and chi-square statistics was the chosen option for calculating differences. Because practically all the differences between different educational levels and types of schools are statistically significant, they are not reported in the text. In contrast, differences between males and females are more diverse. However, knowledge of such differences can be interesting, but is of little practical value for the improvement of schoolwork, or informal education that takes place in the general public realm, because designing courses based on gender differences is an unacceptable practice in the authors' institutions.

Results and comments

Concept of reproduction and basic concepts of genetics

Open-ended tasks (Table 2) were provided to check the knowledge levels about the concept of reproduction and the basic genetics necessary to understand heredity.

Table 2. *Results of responses to open-ended tasks dealing with reproduction and genetics*

	Tasks	N %	Missing %	Marks		
				2	1	0
1	Provide a brief definition of reproduction.	277 89.4	33 10.6	71 22.9	95 30.6	111 35.8
2	Explain the difference between sexual and asexual reproduction at the level of organisms.	258 83.2	52 16.8	25 6.1	165 53.2	68 21.9
3	Explain sexual reproduction with the inclusion of meiotic division.	141 45.5	169 54,4	17 5.5	67 21.6	57 18.4
4	Your neighbour planted a beautiful willow tree; however, you cannot find a retailer anywhere to buy one. Explain how you can reproduce it without seriously harming the mother tree.	196 63.2	114 36.8	135 43.5	42 13.5	19 6.1
5	Farmers buy hybrid maize seeds every year, even if they can save part of their own grain crop to be sown next year. Explain the main reason(s) for their decision.	156 50.3	154 49.7	21 6.8	12 3.9	121 39.0

	Tasks	N %	Missing %	Marks		
				2	1	0
6	Provide your definition of genes.	221 71.3	89 29.7	61 19.7	102 32.9	58 18.7
7	Explain the relation between genes, chromosomes, and DNA.	200 64.5	110 35.5	68 21.9	46 14.8	86 27.7

One important aspect of the information presented in Table 2 is the missing answers. While almost 90% of students provide their definition of reproduction, the inclusion of meiotic division in the task resulted in the dropping out of more than half (54.4%) of the respondents. If we add those who refused to answer the whole questionnaire, arguing that it was too difficult, to the numbers, the quality of knowledge about reproduction, as held by adolescents and young adults, can be seriously questioned. We can gain better insight via analysis of individual tasks.

The first task (1) asked students to provide their first association with the word 'reproduction'. From a range of answers (raw data not provided), it was possible to conclude that their prevailing associations were directly and indirectly connected to humans. The most frequent category (116; 37.4%) of answers named sexuality, specifically human sexuality. The second category (83; 26.7%) consisted of answers around the concept of new life, and in the third category (58; 18.7%), there are answers concerning the biological concepts of species and population. Below the 10% level was the fourth category (18; 5.6%), grouping answers at the cellular and sub-cellular levels; and in the fifth category (8; 2.5%), non-human organisms are mentioned. The remaining answers are presented by a single response, with a great diversity. The most frequently identified misconception was that reproduction is the fusion of male and female sex cells, or a human instinct. From the frequencies of answers, it was possible to recognize that reproduction as a biological phenomenon is not recognized by most respondents as a universal quality of all organisms, but is seen as confined to human beings, thus confusing biological function with social ones (Meston & Buss, 2007).

In Task 2, when asked to explain the difference between sexual and asexual reproduction, only 25 (8.1%) explained the difference by explicitly mentioning the recombination of genetic material. Most of them (53%) provided, under particular circumstances, partially correct answers: e.g. that two individuals are necessary for sexual reproduction. The most frequent incorrect answer was that asexual reproduction of plants is pollination. One surprising discovery was that 51 (16.5%) respondents believe that artificial fertilization in humans constitutes asexual reproduction.

Meiotic division (Task 3) is a basic process in the formation of haploid cells (gametes and spores) from diploid ones. Knowledge about the connection between meiotic division and asexual reproduction (e.g. spore formation) was excluded from the expected answer by the inclusion of the word 'sexual' in the statement of the task. Even if meiotic division is a key process assuring diversity, only a minority connected meiotic division with the formation of haploid cells, or the formation of gametes. Another confirmed misconception was that meiotic division appears after copulation of gametes: a mistake that might somehow be rooted in the teaching of metagenesis in plants.

The understanding of vegetative reproduction (cloning) as a type of asexual reproduction at the level of organisms was addressed by Task 4. The surprise is the relatively large number of them (36.8%) who did not even attempt to give an answer about the common, everyday practice of vegetative plant reproduction, showing that school science is disconnected from everyday experience. This results in correspondents answering incorrectly the statement 'Cloning is an exclusively artificial process' (Table 7), showing that many students do not recognize cloning as a process that occurs naturally, and they connect it to artificial practices. However, among those who did provide answers, the number (57%) who answered correctly or partially correctly answered greatly outnumbered those (6.1%) who provided incorrect answers.

Task 5 was the greatest challenge for students, and only a minority provided correct answers, showing that school science is disconnected from an understanding of everyday practices, such as gardening or animal breeding.

Without understanding the basic concept of a gene (Task 6), it is difficult to understand heredity. As correct answers, even though not consistent with current definitions (Gerstein et al., 2007; Smith & Adkison, 2010), were acknowledged statements such as that a gene is a basic material unit or carrier of heredity; and at the molecular level, that a gene is part of a DNA molecule at a definite position on the chromosome, etc. Partially correct answers mostly comprise mentioning only a particular gene function, such as coding of protein, while omitting aspects like regulatory functions or synthesis of ribosome RNA. One prevailing misconception was that a gene is a double helix containing all information about an individual, showing genetic determinism (Castéra & Clément, 2014).

Marked as correct and partially correct answers (36.7%) about the relation between genes, chromosomes, and DNA (Task 7) were those where the mention of (one) correct relation was provided, e.g. that chromosomes contain DNA, and that genes are situated on chromosomes, etc. A common mistake was to change the order, e.g. to say that the gene contains the chromosome.

More than one third of respondents did not answer, thus indicating flawed knowledge.

Table 3. *Correlations (Spearman's rho) between responses to the tasks provided in Table 2). Correlations were calculated for those, who answered all tasks (N=98)*

	Task 2				
Task 3	.304**	Task 3			
Task 6	.135	.196	Task 6		
Task 7	.181	.250*	.217*	Task 7	
Task 4	-.192	.105	-.065	.138	Task 4
Task 5	.054	-.081	-.114	.012	-.070

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

From Table 3, it can be seen that the correlations (Spearman's rho) between the answers to the tasks presented in Table 2 are low or even negative. In the matrix were included only those who answered all items (N = 98). We can interpret the results as showing that knowledge at one level is not necessarily transferred to other levels and that knowledge is fragmented and unconnected to a coherent network. Weak positive correlations show in some cases that only a minority of the students are able to link knowledge from different levels into a coherent whole. Moreover, two tasks (4 and 5) correlate negatively with other tasks. Common to both these tasks is that they are somehow practical, and connected with a real-life understanding of the world, marking the separation between school science and 'real life', everyday practices.

Knowledge and understanding of mitotic division

Mitotic division is one of the cornerstones in understanding reproduction in eukaryotes and the comprehension of contemporary topics such as cloning. A figure showing the basic phases of mitotic division (five stages) as presented in a number of textbooks was used as backup information for three tasks (Table 4). Simplified inner structures (nucleus, cytoplasm, mitotic spindle and chromosomes) were shown in the figure. The first task was graded on a scale of two, one, zero, and the latter two on a scale of correct (1) and incorrect (0).

Table 4. *Results of answers concerning knowledge and understanding of mitotic division*

	Tasks	N %	Missing %	Marks		
				2	1	0
1	Provide the name of the cell division in the diagram.	193 62.3	117 37.7	7 2.3	113 36.5	73 23.5
2	Sort the cells into the correct order.	178 57.4	132 42.6	*	88 28.4	90 29.0
3	Name the marked structure in the diagram.	175 56.5	135 43.5	*	143 46.1	32 10.3

Note: * two points were not provided

Many missing answers (about 40%) is a common pattern in all three tasks, showing that mitotic cell division was poorly learned and forgotten by a large number of respondents. The correct answer (mitotic division) was given by only seven persons, with the majority answering 'mitosis', which is the correct answer for the division of a nucleus. The source of this partially correct answer is most probably the loose use of the term in teaching. The most frequent misconception was recognition of the process as meiosis. The correct order of the phases, even though taught in elementary school and repeated in most secondary school programmes, was provided by less than one-third of the students. Less than half the students correctly recognize the structure (chromatid); chromosome, chromatid and DNA were counted as correct answers. The high number of missing answers shows a lack of confidence in answering. Because of the diverse response formats, correlations between items were not calculated. However, we can show, by combining other answers from Tables 2 and 7 that there is a missing link between genetics (the relation between genes, chromosomes and DNA; plants and bacteria do not contain DNA), and mitotic cell division and structures involved in it. Additionally, there is indirect evidence of a gap between the recognition of the meaning of the phrase 'identical division' used in common explanations of mitotic division, and cloning, which was perceived by the majority to be an 'exclusively artificial process' (Table 7).

Knowledge about the anatomy of the reproductive organs

Knowledge at the anatomical level was verified using three tasks. In the first task, they had to identify a structure (a pistil in longitudinal section, with a visible embryonal sack) presented as a sketch. About two-third of respondents (201, 66.1%) provided answers, and of these 132 (42.6%) correctly identified the object as a pistil (carpel). The rest (73, 23.5%) incorrectly identified the structure

as an anther. When asked to explain the function of the structure, correct or partially correct answers connected to plant reproduction (reproduction; pollination; fertilization) were provided by 139 (44.8%) of respondents; there were 136 (43.9%) missing responses and 35 incorrect answers (e.g. insemination). We can connect these incorrect and missing answers to the misconception that 'Plants reproduce only asexually' (see Table 7).

The anatomy of human reproductive organs was assessed using two tasks. We provided blank outlines of two human torsos in the frontal position, and correspondents were instructed to sketch and name the male and female reproductive organs, using the outlines.

Table 5. *Results for knowledge of female reproductive organ anatomy*

Organ	N %	Missing %	Codes*									
			1	2	3	4	5	6	7	8	9	10
Vagina	200 64.5	110 35.5	124 40.0	4 1.3	48 15.5	9 2.9			1 0.3	11 3.5	2 0.6	1 0.3
Ovaries	151 48.7	159 51.3	66 21.3	55 17.1	7 2.3	15 4.8	2 0.6			3 1.0	1 0.3	2 0.6
Fallopian tube	122 39.4	188 60.6	49 15.8	43 13.9	10 3,2	14 4.5	2 0.6	1 0.3			1 0.3	2 0.6
Body of uterus	119 38.4	191 61.6	68 21.9	33 10.6	6 1.9	6 1.9	1 0.3				1 0.3	2 0.6
Labia majora	37 11.9	273 88.1	22 7.1		11 3.5	3 1.0				1 0.3		
Cervix	17 5.5	282 91.0	17 5.5	6 1.9	3 1.0							1 0.3
Labia minora	14 4.4	296 95.5	12 3.8		1 0.3					1 0.3		
Clitoris	8 1.9	302 97.4	6 1.9		1 0.3					1 0.3		
Greater vestibular glands		310 100,0										

Note: Codes* (0: missing; 1: correct sketch, correct label, in the correct position; 2: correct sketch, correct label, in an incorrect position; 3: correct sketch, missing label, in the correct position; 4: correct sketch, missing label, at incorrect position; 5: correct sketch, incorrect label, at correct position; 6: correct sketch, incorrect label, in the incorrect position; 7: anatomically incorrect sketch, correct label; 8: missing sketch, organ labelled in the correct position; 9: missing sketch, incorrect position, labelled; 10: organ named by only a word (listing).

Table 6. *Results for knowledge of male reproductive organ anatomy*

Organ	N %	Missing %	Codes*									
			1	2	3	4	5	6	7	8	9	10
Penis	231 74.5	79 25.5	131 42.3	18 5.8	57 18.4	9 2.9	1 0.3	1 0.3		4 1.3	8 2.6	2 0.6
Testicles	227 73.2	83 26.8	65 21.0	69 22.3	26 8,4	59 19.0		1 0.3	1 0.3	3 1.0	1 0.3	2 0.6
Scrotum	11 3.5	299 96.5	6 1.9	1 0.3	3 1.0	1 0.3						
Vas deferens	43 13.9	267 86.1	22 7.1	16 5.2	1 0.3				3 1.0			1 0.3
Prostate	33 10.6	277 89.4	13 4.2	14 4.5					3 1.0		1 0.3	2 0.6
Epididymis	13 4.2	297 95.8	12 3.9	1 0.3								
Seminal vesicles	9 2.9	301 97.1	4 1.3	3 1.0		1 0.3		1 0.3				
Urethra	8 2.6	302 97.4	6 1.9	2 0.6								
Bulbourethral gland		310 100										

Note: For coding, see Table 5.

Both tables (Table 5, Table 6) reveal a large number of missing values. About a quarter of students failed to attempt these tasks. Their number corresponded with missing values for the penis and the vagina. We cannot imagine that adolescents and young adults can be truly unaware of the existence of these two organs, but for some reason they did not even attempt to sketch the reproductive system. Prokop and Fančovičova (2006) recognized the same pattern; missing sketches were attributed to the complexity of the female and male reproductive systems, or to the small area provided for the sketch, and subjective norms concerning what should or should not be drawn, according to personal attitudes. From our study, we cannot reach any affirmative conclusions about the reasons for not attempting a drawing, so our conclusions are based on those who started the task. Interesting side comments from some students were that they could only draw the reproductive from the side projection, in the way commonly present in textbooks. However, by analysing the figures of those who drew at least one structure, we can conclude that knowledge of the inner anatomy of human reproductive organs is clearly shallow. A difference in the levels of knowledge about the male and female reproductive systems exists. Students exhibited far better knowledge about the female reproductive system

and could provide details, a finding which is probably connected to topics such as pregnancy and the menstrual cycle, where knowledge about the reproductive organs is essential. The most frequently sketched and labelled structures were the ovaries, fallopian tubes, uterus and vagina, but they neglected to sketch external parts, which are not essential to an understanding of processes such as the menstrual cycle, birth control and pregnancy. Some of them sketched breasts on the female torso, possibly because of a confusion between primary and secondary sex characteristics. Sketches of the male reproductive system were in most cases reduced to the penis and testicles. Almost nobody named the scrotum, and in many cases, the testicles were positioned in the abdomen. It comes as a surprise that nobody, not even those who finished their secondary education with the Matura examination in Biology, could name the vestibular and bulbourethral glands, and only eight positioned the clitoris in the diagram, indicating that topics such as arousal and coitus are left to informal sources, while the social function of sexuality is commonly reduced to contraception and sexually transmitted diseases.

Two-tier question on asexual reproduction in humans

Understanding of the difference between sexual and asexual reproduction was tested by a two-tier question about whether humans can reproduce asexually. Only 11 (3.5%) students failed to answer, and 15 (4.8%) marked the 'Do not know' option, thus showing confidence in their knowledge. The affirmative 'yes' was marked by 56 (18.1%) and 'no' was marked by 228 (73.5%) students. In the second part, they were asked to provide an explanation of their answer; 129 (41.6%) failed to answer, and only 43 (15.9%) of students were able to answer correctly or at least partially correctly. Four students answered that identical (mitotic) division of a fertilized egg cell could be recognized as asexual, showing deeper understanding. The others connected asexual reproduction with cloning, or thought that asexual reproduction appears after sexual reproduction in the formation of identical twins. A total of 138 (44.5%) of students provided incorrect explanations, showing deep misunderstanding of the concept of reproduction. Again, there emerges the concept that artificial fertilization is asexual reproduction; this is expressed in a number of ways using words, such as 'children from a tube'. The anecdotal answer was that asexual reproduction is 'when boys do it by themselves'.

Two-tier question, about whether two sperm can fertilize an egg cell

As in the previous question, only a minority (13, 4.2%) failed to answer or marked the 'Do not know' (21, 6.8%) option. Affirmative 'yes' was marked

by 213 (68.7%) and 'no' by 63 (20.3%). However, when asked for an explanation, only 32 (10.3%) provided correct or partially correct answers. Only six students correctly stated that such an incident could occur but that such a fertilized egg is aborted. As partially correct, we recognized answers in which it was explained that after fertilization by the first sperm, the egg cell activates a layer that prevents other sperm from penetrating the cell. In addition to the 111 (35.8%) missing answers, 167 (53.9%) were incorrect. The most common identified misconception was that this is the way twins are formed, indicating that they missed the connection between the outcomes of identical (mitotic) and meiotic (division) and processes at the chromosome (genome) levels.

Table 7. *Frequency distribution of answers to a variety of statements directly and indirectly connecting reproduction, inheritance with genetics. Correct answers are in parentheses*

Task ID	Statement	Missing %	Correct %	Incorrect %	Do not know %
1 (1)	If parents have brown eyes, their child cannot have blue eyes. (No)	2 0.6	**232** **74.8**	61 19.7	15 4.8
2 (31)	If a rabbit and a cat have intercourse, the offspring are rabbits with short ears. (No)	6 1.9	**203** **65.5**	31 10.0	70 22.6
3 (29)	Plants do not contain DNA. (No)	6 1.9	**185** **59.7**	74 23.9	45 14.5
4 (18)	The human embryo receives its food from mother's blood system. (Yes)	6 1.9	**182** **58.7**	69 22.3	53 17.1
5 (32)	During sexual reproduction, the sexual organs must be in contact. (No)	4 1.3	**169** **54.5**	116 37.4	21 6.8
6 (33)	Several males must fertilize a cat, otherwise, all offspring will be of the same colour. (No)	2 0.6	**168** **54.2**	82 26.5	58 18.7
7 (25)	Bacteria do not contain DNA. (No)	6 1.9	**162** **52.3**	80 25.8	62 20.0
8 (24)	Plants reproduce only asexually. (No)	1 0.3	**161** **51.9**	114 36.8	34 11.0
9 (5)	Hypophysis influences sexual glands. (Yes)	7 2.3	**159** **51.3**	24 7.7	120 38.7
10 (17)	During prenatal development, the human embryo breathes with lungs. (No)	8 2.6	**158** **51.0**	38 12.3	106 34.2
11 (12)	Fertilization occurs in the human uterus. (No)	2 0.6	**158** **51.0**	125 40.3	25 8.1
12 (14)	The male determines the sex of a human new-born. (Yes)	4 1.3	131 42.3	**134** **43.2**	41 13.2
13 (6)	Hermaphroditism means the same as asexual reproduction. (No)	7 2.3	123 39.7	23 7.4	**157** **50.6**
14 (23)	By using a brush, someone can pollinate solely anemophilous (wind-borne) plants. (No)	7 2.3	105 33.9	82 26.5	**116** **37.4**

Task ID	Statement	Missing %	Correct %	Incorrect %	Do not know %
15 (28)	A newt is an intermediate stage in the development of frogs. (No)	5 1.6	101 32.6	**126** **40.6**	78 25.2
16 (20)	The umbilical cord is connected to the mother's small intestine, which supplies food to the embryo. (No)	5 1.6	90 29.0	**148** **47.7**	67 21.6
17 (7)	Some organisms can develop from unfertilized eggs. (Yes)	8 2.6	86 27.7	**145** **46.5**	71 22.9
18 (10)	Cloning is an exclusively artificial process. (No)	5 1.6	83 26.8	**195** **62.9**	27 8.7

Note: highest values are in bold.

The statements presented in Table 7 tested a number of potential misconceptions. The difference between the results in this table and those achieved by other forms of assessment (open ended, two-tier or drawing) is the low number of missing answers. From the table, it can also be seen that respondents answered any particular answer correctly answered only in 25% to 75% of cases, and that only ten of the eighteen items were answered correctly by more than half the respondents. The best result was achieved on the item about the recessive inheritance of eye colour, and the worst on the recognition of cloning as a naturally occurring process. For some answers, we can accept that the apparent lack of knowledge is the result of uncertainty because of the terminology used or because the topic was not 'covered' by curricula. An example of such knowledge is the statement that 'Some organisms can develop from an unfertilized egg'. However, the answers given to some other items clearly indicate that some students lack many basic concepts of biology, such as reproductive barriers between species, the role of DNA in an organism, and/or pregnancy. An example in point is the inability to correctly answer in the case of the statement, that 'The umbilical cord is connected to mother's small intestine from where it supplies food to embryo' revealing a deep misunderstanding of foetal development. For some answers, we can confirm, that they only confirm our knowledge revealed from our studies on genetics and biotechnology (Šorgo & Ambrožič-Dolinšek, 2009, 2010; Šorgo, et al., 2011; Šorgo, et al., 2014), while the rest only confirm our suspicions about the poor quality of biological knowledge held by a number of students.

Table 8. *Correlations (Spearman's rho) between responses to the tasks provided in Table 7. Correlations were calculated for those who completed all tasks (N=269)*

	Task1	Task2	Task3	Task4	Task5	Task6	Task7	Task8	Task9	Task10	Task11	Task12	Task13	Task14	Task15	Task16	Task17	Task18
Task1	1.000																	
Task2	.093	1.000																
Task3	.042	.082	1.000															
Task4	.070	.023	-.026	1.000														
Task5	.020	.101	.071	.035	1.000													
Task6	.054	.104	.170**	-.001	.106	1.000												
Task7	-.070	.115	.170**	.057	.035	.078	1.000											
Task8	-.034	.037	.108	-.043	.252**	.069	.172**	1.000										
Task9	-.001	.096	.056	.160**	-.023	.113	.160**	.075	1.000									
Task10	.066	.132*	.018	.200**	.128*	.107	.027	-.014	.243**	1.000								
Task11	.024	-.026	-.014	.053	.163**	.062	.101	.119	-.001	-.071	1.000							
Task12	-.023	-.035	.067	.119	-.029	.071	.080	.019	.151*	.096	-.022	1.000						
Task13	.007	.136*	-.004	.216**	.036	.111	.076	-.060	.198**	.249**	.013	.017	1.000					
Task14	.046	.244**	.198**	.002	.033	.191**	.124*	.038	.130*	.153*	-.097	.105	.149*	1.000				
Task15	.111	.022	.240**	.065	.050	.070	.115	.077	.137*	.124*	-.023	.116	.082	.222**	1.000			
Task16	.058	.042	.047	-.079	.128*	.083	.105	.111	-.039	-.004	.040	-.026	.046	.160**	.133*	1.000		
Task17	-.037	.231**	.100	.152*	.117	.021	.189**	-.056	.025	-.003	-.137*	.014	.084	.185**	.095	.048	1.000	
Task18	-.026	.139*	.030	-.074	.213**	.097	.043	.215**	.027	.021	.045	-.091	-.115	.109	.084	.095	.019	1.000

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
c List wise N = 269

From the correlation matrix (Table 8), it is again evident that correlations between items are low, and in some cases even negative, showing that knowledge about reproduction is not being connected in a coherent network, thus confirming the results from Table 3. Moreover, when comparing two conceptually identical items, such as 'Bacteria do not contain DNA' and 'Plants do not contain DNA', it was possible to recognize that most of those who correctly answered one of the item, gave an incorrect answer to the second one in most cases. (Rho = .169). We do not have a good explanation for this, but probably the problem lies in the patchy teaching of similar basic concepts.

Conclusions

From the responses of our sample (N = 310) of adolescents and young adults, we gain an impression about their comprehension of reproduction, which is one of the most important biological issues. We cannot be satisfied with these findings, especially when we know that more than 200 recipients of the questionnaire refused to answer, arguing that the questions were simply too difficult for them. Among those who answered, a large number of missing, or 'do not know' responses forms a constant pattern. Because the items are largely based on textbook knowledge, missing answers can be attributed to a lack of knowledge and not to personal reasons (Prokop & Fančovičova, 2006). Given the fact that at least 34 respondents finished their secondary education with Biology as an elective Matura examination, and that 120 respondents are students in tertiary education, the results (e.g. the inability to sketch the reproductive organs) are disturbing. Our study confirms the familiar challenge of building a consistent body of knowledge on the genetic–inheritance axis (Lewis & Wood-Robinson, 2000), expanding it to the anatomy and physiology of reproduction. These respondents already have difficulties distinguishing between reproduction as 'The sexual or asexual process by which organisms generate new individuals of the same kind' (AHD, n. d.), and sexuality as a complex network of human behaviours, where the generation of offspring (reproduction) is a possible outcome of such activities. Connections between concepts of reproduction and basic concepts of genetics and cell division(s) are weak; respondents even have problems with the definition of a gene as a basic hereditary unit, and the relations between genes, chromosomes and DNA. At this point, we would like to underscore the quality of elementary school biology and of science (biology) courses in secondary schools, because this will be the last formal contact for most citizens with some of the important topics influencing their life decisions.

The implications for biology teaching as a whole, not only teaching about reproduction, call for a transformation in the methods and strategies of teaching Biology (Science) from the former transmission (Šorgo et al., 2011; Šorgo & Špernjak, 2012) to transformative practices. Teaching multidimensional issues, such as reproduction, as a biological discipline-based approach, where one issue is split into fragments and taught in a mosaic fashion at different hierarchical levels, sometimes years apart, with the faint hope that students will construct a picture from pieces by themselves, is not producing results to be proud of. As can be revealed from the present study, the formation of coherent concepts does not happen; moreover, unconnected pieces are easily lost from memory. The pattern can be recognized in the open-ended and two-tier questions, where students answer the first part correctly but are incapable of providing an explanation for their decisions. The findings are parallel with the findings on the knowledge levels of Slovenian students as revealed by the PISA and TIMSS studies, which show that students are weak in comprehension (Štraus & Markelj, 2011). Our study only indicates a problem and does not provide solutions. We can only say that recent educational strategies have not produced the expected results. From the range of strategies, plausible outcomes can be expected from an approach proposed by Knippels (2002). She proposed a strategy in which the teacher moves between different organisational levels.

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Personal Constructions of Biological Concepts – The Repertory Grid Approach

Thomas J. J. McCloughlin*[1] and Philip S. C. Matthews[2]

This work discusses repertory grid analysis as a tool for investigating the structures of students' representations of biological concepts. Repertory grid analysis provides the researcher with a variety of techniques that are not associated with standard methods of concept mapping for investigating conceptual structures. It can provide valuable insights into the learning process, and can be used as a diagnostic tool in identifying problems that students have in understanding biological concepts. The biological concepts examined in this work are 'natural kinds': a technical class of concepts which 'appear' to have invisible 'essences' meaning carrying more perceptual weight than being perceptually similar. Because children give more weight to natural-kind membership when reasoning about traits, it would seem pertinent to apply such knowledge to deep-level research into how children reason in biology. The concept of natural kinds has a particular resonance with biology since biological kinds hold the distinction of being almost all natural kinds, such as when the same 'stuff or thing' takes many different forms. We have conducted a range of studies using a diversity of biological natural kinds, but in this paper, we wish to explore some of the theoretical underpinnings in more detail. To afford this exploration, we outline one case-study in a small group of secondary school students exploring the concept of 'equine' – that is, what is an equine? Five positive examples were chosen to engaged with by the students and one 'outlier' with which to compare the construction process. Recommendations are offered in applying this approach to biological education research.

Keywords: repertory grid analysis; biological concepts; mapping; natural kinds

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Osebnostni konstrukti bioloških konceptov – pristop repertoarnih mrež

Thomas J. J. McCloughlin in Philip S. C. Matthews

Prispevek obravnava analizo repertoarnih mrež (ARM) kot orodje za preučevanje predstav bioloških konceptov študentov. ARM nudi raziskovalcem vrsto tehnik, ki niso povezane s standardnimi metodami konceptualnih zemljevidov za raziskovanje konceptualnih struktur. Zagotavlja lahko pomembne vpoglede v učni proces in je lahko uporabljen kot diagnostično orodje za definiranje problemov, s katerimi se spoprijemajo študentje pri razumevanju bioloških konceptov. Biološki koncepti, preučeni v tem prispevku, so »naravne vrste«: tehnični razred konceptov, za katere se »zdi«, da imajo nevidne esence večzaznavne teže, kot so zaznavno podobni. Ker dajejo otroci večji pomen uvrščanju naravnih vrst, ko sklepajo o značilnostih, se zdi koristno takšno znanje aplicirati v poglobljena raziskovanja o sklepanjih otrok v biologiji. Koncept naravnih vrst ima posebno resonanco z biologijo, saj biološke vrste vsebujejo razlikovanje, da so skoraj vse naravne vrste, kot na primer takrat, ko enaka »stvar ali zadeva« zavzame več različnih oblik. Opravili smo vrsto raziskav, uporabljajoč raznolikost bioloških naravnih vrst, ampak v tem prispevku želimo podrobneje raziskati teoretične podstati. Da si lahko dovolimo to preučevanje, orišemo študijo primera majhne skupine učencev predmetne stopnje, ki so preučevali koncept »konj«, tj. kaj je konj. Izbranih je bilo pet pozitivnih primerov koncepta in en primer osamelca, s katerim si pomagajo v procesu konstrukcije. Podana so priporočila za apliciranje tega pristopa v raziskovanju biološkega poučevanja.

Ključne besede: analiza repertoarnih mrež, biološki koncepti, mapiranje, naravne vrste

Introduction

The field of biology education has been enriched by contributions from anthropology and cognitive science, particularly in elucidating concepts associated with natural kinds (Kripke, 1971, 1972; Mayr, 1942; Mill, 1843; Putnam, 1975; Quine, 1969; Wilkerson, 1995). Natural kinds can be considered in a weak and a strong sense. The strong sense is that natural kinds are precisely those kinds that science seeks to identify. The identification of a natural kind by science is a claim to have established how nature is divided at one of its many 'joints'. Thus, physics claims that the electromagnetic field is a natural kind, chemistry claims that the stuff labelled 'water' is just that material with composition H_2O and is a natural kind. Historically, one aim of biology has been to delimit the notion of species to represent a set of natural kinds. However, given the difficulties that have accompanied this pursuit, there is reason to doubt if the concept of a species will be identified as representing a natural kind; therefore, a weak sense of natural kind is more relevant to biology where exceptions are permitted, and which we take as a demonstrative definition. See, for example, Wilkerson (1995) for a discussion of this point, and of natural kinds in general. Another sense of natural kinds is that they represent entities that may appear only to be definable, or describable, in terms of hidden essences. Often, they are the stuff of 'folk-biology', and as such have been investigated by many authors. Furthermore, biology education has been enriched by contributions from anthropology and cognitive science. The following are most noteworthy:

- Atran (1995a, 1995b) who proposed folk-biological constraints on taxonomies and the existence of a natural kind module in the mind;
- Keil (1989) who experimented with transformations on natural kinds;
- Springer and Keil (1991) and Gelman and Wellman (1991) who explored essentialistic thinking with respect to natural kinds;
- Wellman and Gelman (1992) who described biology as an innately constrained domain;
- Hatano and Inagaki (1994) who postulated the existence of a naïve biology which is an adaptive, causal, explanatory framework encompassing living things.

In particular, young children (and other lay people) have an intuitive sense of difference between types of animal. They recognize that, for example, lions and tigers may not interbreed, or that a tiger remains a tiger even if its manifest signs, such as stripes, are absent (viz Keil, 1989). It appears that humans have an innate sense of living creatures being of different kinds to

inanimate matter. However, we believe that it is the sense that (young) humans have of the hidden essences of natural kinds that makes at least certain aspects of academic biology difficult to understand. The key problem is that the hidden essences of folk biology rarely, if ever, coincide with the natural kinds identified by the scientific discipline(s) of biology. Thus, as a biology teacher, one may be faced with the task of displacing or perhaps over-riding a student's strongly held belief. This facet of teaching and learning is, of course, familiar from the constructivist paradigm that has tended to dominate science education research in the last 25 years. We are at present undertaking a study of students' conceptions of species, particularly of equines. The aim of the work is to identify communalities and differences in the ways that students conceive of members of different species. We have found that repertory grid analysis (RGA), which is a method of investigating conceptual structures commonly used in the psychological literature, can be extremely useful in this research. In this paper, we give a brief account of RGA and illustrate some aspects of its utility in relation to a small pilot study undertaken with a group of school students. Repertory Grid analysis may be well known to practitioners in science education; however, the application to which it is being put here is a departure from previous research and practice. Further, it is our intention to demonstrate that whereas in the study 80 presented the topic was categorisation (of equines), it is suggested that all biological concepts may be represented using RGA.

Concept mapping and repertory grid analysis

The different types and uses of assessment techniques were reviewed by Novak and Mintzes (2001). However, RGA was not discussed by them; nor was it mentioned in Fisher, Wandersee and Moody (2000) which addressed the role of knowledge mapping in promoting meaningful learning in biology. Mohapatra and Parida (1995, pp. 663–681) used a concept graph technique to identify the location of alternative conceptions. Their technique is derived from Novak's (1990) system of using concept maps and vee diagrams as two metacognitive tools to facilitate meaningful learning. Mohapatra and Parida's system produces a matrix, the elements of which represent the strength of links between pairs of concepts as conceived by the corresponding group of subjects, and which have been scaled to values between 0 and 1. Lawson (1997, p. 292) points out that concept mapping is one of many techniques for externalising 'internal psychological structure'. He believes that concept mapping is similar to procedures which make use of multivariate statistical techniques of cluster analysis and multidimensional scaling procedures that repertory grid analysis

utilises. Lawson (1997) also states that the repertory grid technique shares the same objective as concept mapping in attempting to produce 'a representation of the structure of a semantic space'. RGA has been widely put to use as a tool by psychoanalysts and psychiatrists to investigate the structure of a person's personality with a view to locating defects and making efforts to remedy afflictions from which the person might be suffering. As such, RGA is a key part of personal construct psychology (PCP), that proposes that a person constructs for him/herself a representation of their own reality. In such a system, the person is held to become analogous to a scientist, testing, making predictions, analysing situations, inferring and so on, as a means for construction. Kelly's often quoted phrase 'man as scientist' emphasises this point (Kelly, 1953/1991). However, such claims should be treated with caution because the analogy is simplistic (cf. Dunbar, 2002.). Kelly's influence has extended beyond the clinical setting and into educational psychology, especially into the constructivist paradigm. To use his terminology, a 'construct' is a way in which a person views aspects of the world as being similar or dissimilar. In this respect, constructs are fundamentally bipolar. Although Kelly did not intend his method to be applied to biological kinds such as horse, cow, sheep, etc., or indeed concretistic concepts from any of the disciplines of science, the purpose of this paper is to show that it does work as a method for conceptual analyses involving such kinds. Indeed over 30 years ago, Kelly's repertory grid technique was recommended as a technique to probe learners' prior knowledge (Sutton, 1980, p. 116). RGA has also been used in investigations of students' conceptual structures in some fields of physics (Fetherstonhaugh, 1994) and attitudes to science (Happs & Stead, 1989). RGA makes use of multidimensional scaling (MDS) and other statistical techniques, such as principal component and factor analysis, that in themselves assume nothing of the background theory of RGA or PCP for their application. Such techniques have been used to good effect in, for example, the work of Atran (1999, p. 165), who used MDS to characterise the Itzaj snake classification. In passing it is worth noting that the majority of mathematical techniques employed in RGA programs can be found in commonly used statistical packages such as SPSS, Minitab, Statistica, and R. Furthermore, professional biologists have turned to such statistical methods in situations in which it is impossible to distinguish species without the precise measurement of prescribed parameters and executing the required algorithms (morphometric analysis cf. Quinn and Keough (2002)). An example of such a use is outlined below for the purpose of demonstration. It is important to emphasise that we are using the mathematical apparatus of RGA to analyse students' concepts in biology; we are not claiming this approach to be a contribution to PCP. Also, the small-scale study that we

describe was chosen specifically to illustrate the way RGA can be applied in the context of biology education rather than to provide a thorough analysis of the students' conceptual structures.

Atran (1999) appears to have led the way for using organismal classificatory techniques to investigate the mental structures of biological data, by which he represented the mental relatedness of snakes in the minds of The Itzaj Maya. Although biologically, mimics are not closely related to the poisonous snakes they mimic, perceptually they are very closely related, e.g. *Xenodon rabdocephalus* is a mimic of *Bothrops asper*. Atran (1999) reported that the Itzaj Maya are motivated by the survival strategy 'better safe than dead', which constrains an initial classificatory identification. However, the Itzaj were still able to distinguish the mimics from their models. This is a result of a 'principled classification'. Fay et al. (2003) digested DNA samples of *C. depauperata* and, following amplification, separation was carried out using a polyacrylamide gel. The bands produced were scored as either absent or present producing a binary matrix. Principle coordinates analysis was performed on this matrix and axes extracted. This is a common technique in biology, see for example the following: Parnell and Needham (1998); Foley (2000a, 2000b); Blackstock and Ashton (2001); Abbott et al. (2002), Fay et al. (2002); Fay et al. (2003). Such mathematical treatment of the data (the data can be morphological, genetic, or dichotomous) can actually measure the state of such an alternative conception (to formal biology). A novel teaching and learning sequence followed by a repeat of the test could measure the shift in the conception if any, not necessarily conceptions related to classificatory schemata.

Method

A small group of students (n = 11) from a fifth year (student 16–17 years old) class group from the Irish Republic took part in this study. The repertory grid analysis package used was CIRCUMGRIDS III (Chambers & Grice, 1987) working in MS-DOS format. (However, more sophisticated programs are available; see below.) The purpose of the work was to evaluate the use of an RGA program in investigating the ways in which this group of students categorized a set of animals, all but one of which were equines. The equines were: horse, pony, donkey, mule, zebra; and the non-equine was a goat. The purpose of including the non-equine was to discover if, as would be expected, the RGA method would show that this creature was (in relation to the others) considered by the students to be anomalous.

Initially, the students were asked to state what they thought to be key features of some equines, and their responses analysed. The most common six

features they chose were the existence of stripes, the presence of a thick neck, and so on (see below). Note that these features are not necessarily those that are part of the classification system of academic biology. The RGA program was used to investigate how the six features were combined in the students' minds to form their conceptions of each of the six animals. In the terminology of RGA, the animals were used as 'constructs', and the features were the 'elements'. After accessing the menu page of the CIRCUMGRIDS III package, a choice is made of which analysis to use. The subjects were asked to enter data for (i) Bannister-Fransella and (ii) Bieri analyses, two out of a range of six analyses.

(i) Bannister-Fransella analysis compares the same elements and constructs of two grids. Each student entered the names of the six animals (constructs), i.e. horse, pony, donkey, mule, zebra, goat, and the six features (elements); i.e. stripes, thick neck, hardly any mane or tail, horse (equine) shape, chestnut, short face/small head. The program then presented the student with a list of the features and asked which of them is most 'zebra', or zebra-like, most horse-like and so on. The choices were scored on a set of six-point Likert scales, e.g. 'stripes' was scored as 1, and ranged to 'no-stripes' scored as 6. This was repeated for all the feature/animal combinations. The program requires the student to repeat the procedure, thus allowing a check on consistency to be made. The data is converted into two sets of grids (one of which is shown in Table 1) together with a series of measures that we describe below.

(ii) Bieri analysis is a means of eliciting the structure of constructs through ranking elements against constructs; i.e. here, the six features against each of the six animals. The software prompts for the number of constructs and elements (six in each case), and the names of constructs and elements. The program required the student to rank each feature against each animal using a seven point Likert scale ranging from +3 (strongly agree) through 0 to –3 (strongly disagree). For example, suppose a construct is envisaged as a line with, say, 'zebra' being one pole and 'not-zebra' at the other. Then, if 'stripes' is placed on this line, the closer it is placed to the 'zebra' end (limit +3), the more significant this feature is to the student's conception of 'zebra'. The output from the program is another grid, illustrated in Table 2, and various statistical data, much of which is not relevant to our discussion.

Results

1. Bannister-Fransella Analysis

Following the student's input of data, the program outputs the two grids (see Table 1) and, for each of them, it compares the entries for the pairs of animals. It does this by computing the correlation coefficients for each pair and rank ordering them. The ranks are used to calculate a value for the 'intensity', that provides a measure of the degree of structure in the student's system of classification. In our investigation, intensity scores were sometimes found to vary markedly between students, thus indicating considerable individual differences in how the subjects attributed animals to features.

Table 1. *One of the grids of ranks of relevance entered by Student A*

Construct	Stripes	Neck	Mane/tail	Horse shape	Chestnut	Face
Horse	6	2	5	1	4	3
Pony	6	3	5	1	4	2
Donkey	6	2	5	1	4	3
Mule	6	2	5	1	4	3
Zebra	1	4	5	2	6	3
Goat	1	4	5	2	6	3

Another measurement is the consistency between the two grids; in effect, this is a calculation of Spearman's rank correlation coefficient for the combined data of both grids. The interpretation of grids that show low consistency has to be treated with caution. Low consistency indicates a degree of uncertainty in the student's mind about the relation between the features and constructs with which she is presented.

2. Bieri Analysis

In Bieri analysis, the program ultimately produces an output that gives a visual display of the relationship between the elements and constructs. Initially, however, a grid is produced showing the data entered by the student. See Table 2 for the grid entered by Student B. The grid is used to compute a set of correlation coefficients, from which first, second and third principal components are computed using the standard techniques of statistical analysis. In the majority of cases, the variability in the data can be accounted for by just two components

and the first and second components are plotted by the software. If required, the data can be entered into SPSS or similar and a three-dimensional principal components plot can be obtained. Figures 1, and 2 illustrate principal components plots produced by two of the students.

Table 2. *Bieri analysis grid of scores entered by Student B*

Construct	Stripes	Neck	Mane/tail	Horse shape	Chestnut	Face
Horse	-3	2	3	3	-3	3
Pony	-3	1	-1	0	-2	2
Donkey	-3	2	1	0	-2	2
Mule	-2	1	-1	0	-2	2
Zebra	3	2	-2	-3	-2	2
Goat	-3	-2	-1	-2	1	-2

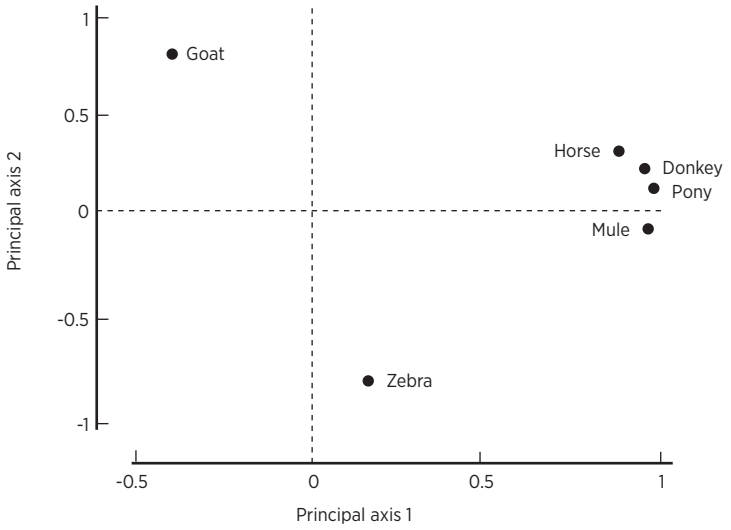

Figure 1. Principal components plot for the date entered by student B (Table 2). Note: for the sake of clarity, the plots in Figures 1 and 2 have been re-drawn rather than simply copied from the RGA program output

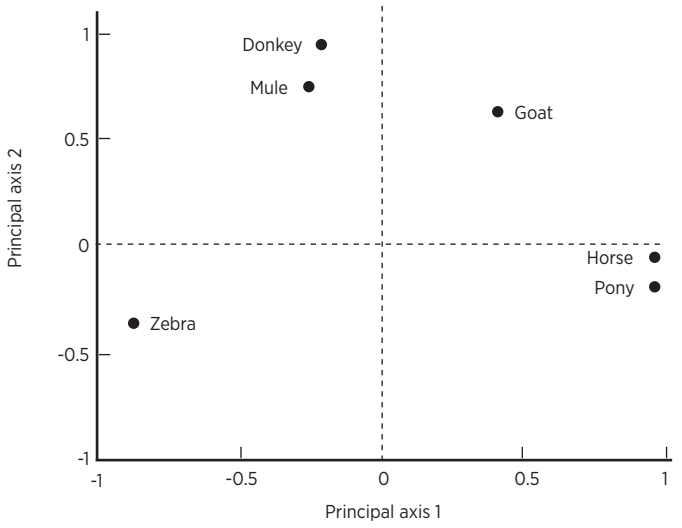

Figure 2. Principal components plot for Student C

A general point is that constructs located close to each other may be interpreted as occupying a similar conceptual space. Figure 1, shows that Student B regards horse, pony, donkey and mule as being very similar. In contrast, this student views goat and zebra as markedly different from those four animals, and from each other. Student C's results plotted in Figure 2 show that he viewed horse and pony as being closely related, as were donkey and mule; but these pairs were separated from each other. The implication is that this student had a subtler way of categorising these four animals than Student B did.

However, zebra and goat are again separated from the other four creatures, and from each other. More advanced repertory grid software goes further and measures the relatedness of the constructs, draws a cluster analysis diagram (resembling a phylogenetic tree), and compares the grids of a relatively large number of individuals, e.g. of a class group. (McCloughlin & Matthews, 2001, 2002). Cluster analysis can be a powerful tool in analysing categorisation data (cf. Bailenson et al. (2002)), and the results of the formal scientific cluster analysis are comparable to the results of Repertory Grid Analysis. For example, the classification (Figure 3) is very different from that below in the cluster diagram (Figure 4) even though the original data was the same. This is because cladistics groups taxa according to special similarity using discrete characters rather than an overall similarity computed from the complete matrix (Schuh, 2000, p. 9). Repertory Grid software (e.g. RepGrid 2.0) typically perform cluster analysis (Figure 4) on both the features and the concepts, and it is

possible to plot concepts within the psychological space of the features. Cluster analysis of the features or attributes of concepts allows the researcher to see if certain features are superfluous to the test instrument. If several features for a number of learners were tightly clustered at, say, 90%, it is unlikely that all those features are needed to gain any meaningful information about the learners' concepts. In both the instances presented here, it must be remembered that what is plotted are mental representations of the learner's conceptions of the concepts encountered.

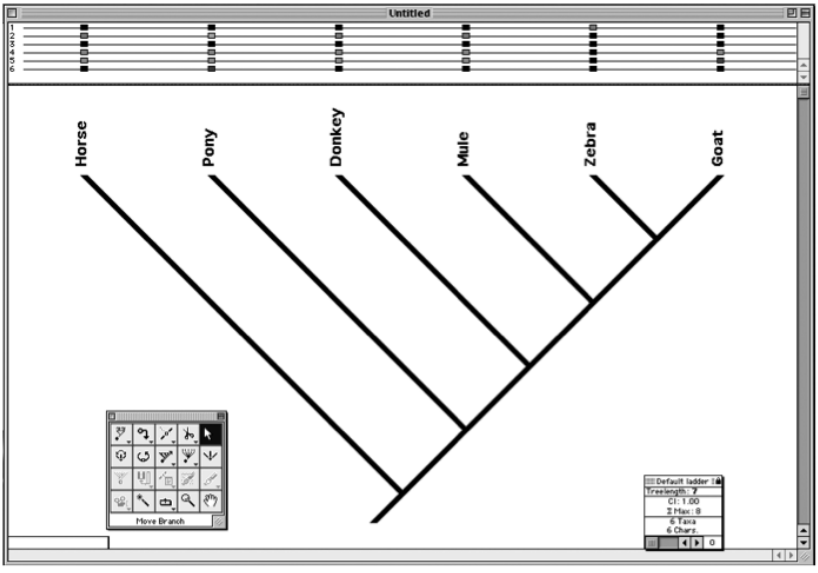

Figure 3. A dendrogram (i.e. cladogram) of the data from Table 1. entered into MacClade™ cladistics software

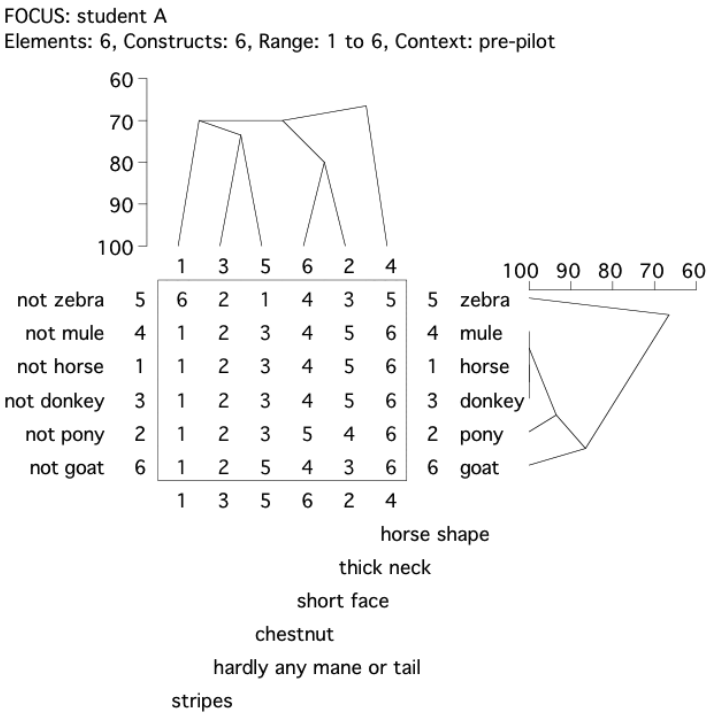

Figure 4. Output of FOCUS program of the RepGrid 2.0 package

Discussion

As mentioned earlier, the Bannister-Fransella printout provides intensity scores for every grid (two for each person) and a consistency score for each pair of grids. The scores and the grids themselves say something about the learner and that which is to be learned. Bannister and Fransella, (1977, p. 60) note that 'The lower the intensities score, the more disordered is one's thinking'. The consistency value indicates the degree of stability between grids. Thus, a low consistency score indicates that the person is a disordered thinker, in the sense that s/he has no decided opinion on the way the elements should be ordered under the constructs. Perhaps paradoxically, low consistency means having the greatest cognitive complexity. If the subject could memorise their rating on the first test and replicate it in the second, the consistency scoring would be compromised; but this situation is unlikely, particularly if a period were to elapse between the tests. More work needs to be done to identify the relationship between complex concepts and intensity scores. If a learning strategy were to intervene between grid elicitations, the educator would hope that the

second intensity score would be higher than the first (unless it was high in the first place). The comparison would indicate the quality of learning. Grids could be used to investigate the nature of the problem in the learning domain if one exists. We have found that it is instructive to compare the grids of learners with those of experts. One should be careful in interpreting principal components plots and taking them at face value.

Contrary to our expectations, one student, D, had linked 'stripes' quite strongly to 'horse' and 'pony' as well as to 'zebra' (although not to 'goat'). That is, D (unlike the other students) did not use 'stripes' as a major way of discriminating between 'zebra' and 'horse'. We discovered the significance of this during an interview with the student. She was a member of the local equestrian club and had held a strong interest in horses for much of her life. She knew that it was possible for stripes to appear on the legs of newly born foals and then fade as they matured.

However, characterising 'zebra' as a striped animal took priority over all other features for all the students, including D. In interviews with the students prior to them completing the grids, it was clear that they knew that zebras are equines ('zebras are horses with stripes'); however, their attention appears to have been constrained by the obvious striped feature of these animals. Indeed, in an earlier remark, we said that we included 'goat' in the list of six animals to see if the RGA method would result in this animal being isolated from the equines. This did, in fact, prove to be the case; however, the separation/isolation of 'zebra' demonstrates the extent to which a single perceptual feature (stripes) can dominate students' thinking. Thus, the relationship between concepts of differing relevancy to the student or the educator may be investigated. Bannister-Fransella analysis is better suited to elucidating the features of structures of biological concepts in the individual rather than in a group unless some further manipulation is done. One form that this can take is tallying the scores for each characteristic (element) of a construct, yielding a matrix for the study group. This, for example, can show the most important feature used to characterise 'horse', 'pony', etc.; and each could be ranked. In our case, eight students believed that the general 'horse (equine) shape' was most important, but only one thought this to be so for a 'short face and small head'. The latter individual was not very familiar with horses, all the others being equestrians. However, even some of these students did not realise how ubiquitous the presence of a chestnut is among the equidae. It is interesting to note that when the students were asked to explain what 'horse (equine) shape' meant, they could not; many stated that 'you just know it or you don't'. One must be careful when proposing that single features (elements) are dominant over others; the fact is that, for example, the

construct, 'horse' is being characterised by the balance of a small set of competing features. In some cases, two different animals might both justifiably an identical score on a particular characteristic. If the repertory technique is done in such a way (as in this case) that all constructs are required to receive a rank or score, then allocating a high score or rank to one element will have a knock-on effect in the allocation of scores/ranks to the other constructs.

An interesting problem is to analyse why different elements may be given a different emphasis by different people. Here the roles of language, experience and culture need to be addressed. The choice of elements in this pilot project was based on perceptual entities, whether they be a part of an animal (e.g. head) or a general essentialistic perception (general equine shape). However, ultimately, behind this interaction of competing features lies the core, the construct, of the species being recognised. The plots in Figures 1 and 2 represent 'maps' of the constructs in element space (element points can also be plotted in construct space). These maps are very different from the mapping techniques discussed in Fisher, Wandersee and Moody (2000) and Novak and Mintzes (2001). However, in our view they can be held to represent maps of a student's conceptual space; or, in simple terms, as 'concept maps', albeit of a special kind.

Educational implications

Repertory grid analysis allows biology educators an access point for research into their students' learning using powerful mathematical tools that are widely available. It is a technique that can usefully be employed over a wide range of ages, perhaps from late primary into tertiary education. Ideas can be elicited, whether finding out prior knowledge, teasing out alternative conceptions or investigating ideas relating to specific tasks set for research purposes. The technique is best suited to researchers until such time that a means for allowing classroom teachers to use it as an assessment tool can be put forward. Even where RGA is put forward as an alternative or form of concept mapping, it is not an advantage to make such a comparison since concept mapping itself has waxed and waned as an assessment and learning tool. The technique can be used diagnostically and allows the biology researcher/educator to gain a visual impression of how a student's concepts are related to each other. It can be used to give an overview of the conceptual structures of a class group. We have found it instructive to compare the plots of students with those of experts. The information contained in the principal components plots of expert and novice can give an indication to what remediation might be necessary to bring those of the students more into line with those of the expert's. Of singular importance is

the fact that the researcher/educator can gain an appreciation of how ideas are modelled or structured by the students. In all these respects RGA can be used by researcher and teacher alike to evaluate teaching and learning. However, rather than being merely an alternative to concept mapping or other assessment techniques, RGA permits the researcher / educator to examine the 'apophatic' aspect of conceptual knowledge: i.e. saying what something IS NOT as opposed to the 'cataphatic' aspect, i.e. delineating what something IS within the same proposition. Concept mapping and other related techniques can be made amenable to mathematics but such application of ranks or scores are elicited differently and are not intrinsic to the method.

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Biographical note

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Dissection of Mammalian Organs and Opinions about It among Lower and Upper Secondary School Students

Andreja Špernjak*[1] and Andrej Šorgo[2]

This article describes the results of a study that investigated the use of the dissection of organs in anatomy and physiology classes in Slovenian lower and upper secondary schools. Based on a sample of 485 questionnaires collected from Slovenian lower and upper secondary school students, we can conclude that dissection of mammalian organs during the courses on Human Anatomy would be a preferred activity for the majority of them. Opinions on such practices are positive, and only a minority of students would prefer to opt out. However, the practice is performed only occasionally in regular classes, or even omitted, and a number of students never participate in it. According to the results, we can suggest the dissection of mammalian organs in combination with alternatives, such as 3D models and virtual laboratories, as a preferred strategy to increase knowledge of anatomy and to raise interest in science. However, students should know that the organs they are dissecting were dedicated to human consumption, or are waste products in these processes. Opt-out options should be provided for those who do not want to participate in such activities.

Keywords: biology laboratory work; dissection; interest in dissection; lower secondary students; upper secondary students

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Seciranje organov sesalcev v osnovi in srednji šoli ter njihovo mnenje o sekciji v razredu

Andreja Špernjak in Andrej Šorgo

V članku so predstavljeni izsledki raziskave o sekciji organov pri urah anatomije in fiziologije človeka v osnovnih in srednjih šolah. V študijo je bilo vključenih 485 učencev in dijakov iz različnih osnovnih in srednji šol. Iz rezultatov lahko sklepamo, da si večina vprašanih pri urah biologije želi več sekcije organov. Učenci in dijaki v večini podpirajo izvedbo sekcije organov in le majhen odstotek vprašanih sekcije med izobraževanjem ne želi izvajati. Glede na rezultate vprašanih sklepamo, da je sekcija organov v slovenskih šolah redka praksa ali pa je med šolanjem sploh ne izvajajo in je popolnoma izpuščena. Ker si večina vprašanih pri urah biologije želi sekcije organov sesalcev kot prednostno strategijo za dvig znanja o anatomiji sesalcev in povečanje zanimanja za naravoslovje, predlagamo izvedbo sekcije v kombinaciji z rabo drugih učnih pripomočkov, kot so 3D-modeli organov ali virtualni laboratoriji. Pri sekciji organov je učence in dijake treba seznaniti, da so bili organi za sekcijo namenjeni za prehrano ljudi ali pa so kot odpadni produkt v procesih predelave hrane. Za učence in dijake, ki pri sekciji ne želijo sodelovati, je treba zagotoviti možnost izbora in pripraviti druge dejavnosti.

Ključne besede: biološko laboratorijsko delo, interes za seciranje, osnovnošolci, seciranje, srednješolci

Introduction

Biology is a discipline about living beings, and there is no scientific evidence about the presence of life outside organisms. Study of the interiors of 'homes of life' is a part of the standard content of biology courses/subjects at the primary and secondary educational levels and is regarded as essential for biology, veterinary and medical students (Macchi, Porzionato, Stecco & Caro, 2014) at the tertiary levels. In formal education, different instructional methods exist to attain knowledge and experience about the internal anatomy of animals and humans. Methods range from expository instructions, as verbal and multimedia presentations, exposition of models and fresh or conserved animals by teachers or teaching assistants, to the first-hand experiences of students as dissection in biology/anatomy classrooms, and in recent times as interactive virtual dissections (Saltarelli, Roseth & Saltarelli, 2014) and use of 3D printed models (Fancovicova & Prokop, 2014; Fredieu, Kerbo, Herron, Klatte & Cooke, 2015; McMenamin, Quayle, McHenry & Adams, 2014). All instructional methods used in anatomy teaching, except dissection itself, have in common that they can be recognised as derivatives of dissection, because there is no alternative to obtaining primary insight inside the bodies of members of the animal kingdom.

Globally, differences between countries in the views and position on dissection exists, largely based on the dominant teaching culture and values of a society, with trends for the exclusion of animal dissection or its replacement by virtual alternatives (Demirhan, 2014; Osenkowski, Green, Tjaden & Cunniff, 2015). For instance, in the USA, the National Science Teachers Association (NSTA, 2005) supports the decision of science teachers to integrate live animals and dissection into the classroom. However, regardless of the support of NSTA authorities, the dissection of a whole animal or organ is a common practice only in some school districts' biology curricula and absent in others (Mattheis, Ingram, Jensen & Jackson, 2015). Schools in five countries (Argentina, Israel, the Netherlands, Slovakia, and Switzerland) do not conduct dissections, and the practice is rare or being phased out in other countries, including England, Sweden, and India (Oakley, 2011). In German biology classes, dissections are required by educational authorities, e.g. by the Ministry of Culture and Education in Lower Saxony (Holstermann, Grube & Bögeholz, 2009). At semi-formal levels, dissection is an obligatory activity of the practical part of International Biology Olympiads (A Guide to the International Biology Olympiad, 2015). In Slovenian schools, dissection of mammalian organs is encouraged by national documents on biology/science education but in practice entirely depends on

the teacher's autonomous decision and discretion to include it in teaching or not. To our best knowledge, studies about the status of dissection in Slovenian schools do not exist, which was one of the main incentives to begin our research.

The dissection of organs as a part of biology laboratory work has been recognised as beneficial with arguments that dissection can help students to develop skills of observation and comparison, discover the shared and unique structures of specific organisms, and develop a greater appreciation for the complexity of life (NSTA, 2005). However, some authors have claimed that animal dissection is a controversial pedagogical practice. In educational contexts, it raises ethical and environmental concerns regarding the killing of animals, the ignoring of animal welfare standards, the weakening of respect for life, and the 'turn-off' factor for some students (Balcombe, 2000; Bishop & Nolen, 2001; Hug, 2008; Jukes & Chiuia, 2003; Marr, 2001; Oakley, 2009; Sapontzis, 1995). As Balcombe (2000) writes, there is an ethical question underlying the justification of killing animals to learn how they work, even if this is thought to be the best way to teach.

In Slovenian schools, teachers are allowed to dissect mammalian organs that have been obtained in a slaughterhouse or butcher shop unless they contain bovine nervous tissues, due to possible BSE transfer. The same is true for other vertebrates, which leaves only the dissection of birds (poultry) and fish. However, the raising of vertebrates as model organisms in a school vivarium is encouraged, but not with the purpose of dissection. Practices of whole body mammalian dissection. such as dissection of rodents has been abandoned in elementary and secondary schools. By using animals or their parts for human consumption, ethical questions are largely reduced, because all dissections in schools are performed on organs or animals for which dissection was not the sole or primary purpose of killing the animal. However, due to different reasons, some students would prefer to opt out of dissection. Since dissection can negatively impact students' self-efficacy beliefs and interest levels, adolescents are not pressured to perform dissection or have contact with dead organs (Holsterman et al., 2009). Based on conversations with teachers, which were part of regular visits to schools by the authors of the present paper, the most common practice is that students are allowed to opt out of dissection without penalty. However, due to school regulations, they are not allowed to leave the classroom: in the most cases, they observe dissection from a distance, following the so-called opt-out scheme (Cunningham, 2000).

Because of ethical concerns about dissection, alternatives have been sought, recently in virtual worlds (Peat & Taylor, 2005). Research based on all educational levels indicates that outcomes pertaining to learning anatomy and

physiology can be met by virtual alternatives, and that students' gained knowledge can be equivalent, and sometimes superior, to traditional dissections (Cottam, 1999; Lalley, Piotrowski, Battaglia, Brophy & Chugh, 2010; Maloney, 2005). In contrast, Kerby, Shukur, and Shalhoub (2011) claimed that while the use of computer simulations and virtual dissection serve as valuable teaching tools, they simply cannot replace hands-on experience that dissection affords. In a review of studies designed to compare the effectiveness of various forms of instruction for first-year medical students, Winkelmann (2007) found that the literature suggests advantages of traditional hands-on dissection, but does not discount the value of alternative methods, including prosection and the use of computerised multimedia imaging programs. Many medical educators view dissection as a learning experience that cannot be replicated through other means. De Villiers and Monk's (2005) review of research on the topic not only revealed ongoing tensions within the field, but also acknowledged the fact that strong support remains for this type of hands-on learning of anatomy despite the increased availability of alternative and virtual experiences. Additionally, as noted by Richardson (2011), even the best virtual dissection activities have inherent contradictions to the fundamental nature of anatomy, physiology, and science in general, as they do not entirely effectively convey the distinction between living organisms and machines and the unpredictability of living organisms and systems. Richardson (2011) warned that virtual dissections may promote misconceptions and lead to overgeneralisation. Most probably, the best learning outcomes are achieved by a combination of real and virtual dissection not as exclusive but as complementary. A body of research shows that a combination of real and virtual, both as used virtual for preparation for virtual dissection or used for confirmation and repetition outperformed using each technique separately (Akpan & Andre, 2000; Akpan, 2002; Smetana & Bell, 2012).

The dissection of human organs is out of scope in Slovenian secondary schools and challenged at university levels. Because linking the structure of organs with function is considered to be a basic science concept, dissections of pig or cow organs are set in the context of human biology in order to illustrate how human organs are built and work (Entrich, 1996; Mattheis, Ingram, Jensen & Jackson, 2014).

Research questions and aim of the study

In Slovenian schools, the dissection of mammalian organs is recommended but, to our best effort, we were not able to find a study about the actual use of dissection in schools or on interest and attitudes toward this practice

among students. This paper intends to contribute to this issue.

Our research questions were as follows:

- Which mammalian organs, if any, do students dissect during their biology laboratory work?
- Which mammalian organs would they prefer to dissect, if any?
- Would participants show more interest in the dissection of organs if they had such experiences from biology/science classes?
- Are there any differences in opinion between participants on the dissection of organs regarding school level and gender?

Methods

Sample and sampling

Our study is exploratory by design, and no interventions were made in classroom practice. The participants for this study were students of six different lower secondary (Level 2 by ISCED, 2011) and six different upper secondary schools (Level 3, ISCED, 2011) from Slovenia. Interested readers can obtain more information on the Slovenian school system from international webpages, e.g. http://www.ukom.gov.si/en/media_room/background_information/education/educational_system_in_slovenia/.

Prior to the survey, permission was obtained from the school authorities. Participants were asked to complete a questionnaire in paper-and-pencil format prepared for the purpose of the study during their regular classes, following the standard protocol. During the initial phase, they were informed about the goals of the research, given specific instructions about filling the questionnaire fields, and guaranteed anonymity. Additionally, they were informed that answering was on a free will basis, so anybody could opt out anonymously by simply returning an unanswered questionnaire at the end of the session, and that no benefits were provided. There were no specific time constraints, but respondents typically needed about 10 minutes to complete the survey. We collected 483 questionnaires. The students were aged between 14 and 18 years old; 280 students were from the 8th grade (179 students; 37.1%) and 9th grade (101 students; 20.9%). From seven high schools, 203 questionnaires were collected (44 students (9.1%) from 1st year, 22 students (4.6%) from 2nd year, and 137 students (28.4%) from 3rd year). We collected 207 questionnaires from boys (42.9%) and 276 questionnaires from girls (57.1%).

Structure of the survey instrument

The questionnaire contained three parts.

Demographics

The first part of the questionnaire solicited demographic data about school grade and gender.

Actual experiences of dissection and opinions about what items should be dissected

The second part required participants to mark in yes/no format if they had examined or touched or dissected some mammalian organs during biology classes, and if they had, which organs (see Table 1). In the same table, they also had to mark in yes/no format which organs they would like to examine or touch or dissect during school laboratory sessions.

Results of actual experiences with dissection of mammalian organs (Cronbach's alpha = 0.612) can be recognised as biased, because of the small number of examined classes, which can influence outcomes because of the habits and practices of the small number of teachers teaching our sample; this does not permit the transfer of findings to the whole population of students.

However, the results of opinions on which mammalian organs should be dissected (Cronbach's alpha = 0.862) can be recognised as representative.

Attitudes toward dissection as a school practice

The third part was a scale with 12 statements created to explore participants' attitudes toward dissection as a school practice. The answering format was a 5-point Likert scale, as follows: 1 = definitely disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = definitely agree. The Cronbach reliability coefficient for the scale is 0.87, which can be considered appropriate for further analyses.

Statistical procedures

The statistical procedures employed were as follows:

a) Descriptive statistics: prior to statistical analysis, variables were checked for normality. The Kolmogorov-Smirnov Z test (KS test) at the 0.05 significance level was used. Because all variables do not follow normal distribution, nonparametric statistic was preformed (Erceg-Hurn & Mirosevich, 2008). Due to skewed data frequencies, mode and median are reported. Means and standard deviations are reported only to obtain a

better impression of data distribution. The reliability of the scales was explored by the calculation of Cronbach's alpha, and by further analysis with the 'alpha if item deleted' procedure in order to foresee possible improvements of the scales. Due to satisfactory alpha levels and to preserve the breadth of the scale, no items were deleted from a pool even if an increase in alpha was predicted.

b) Principal Component Analysis with Direct Oblimin rotation was used to explore the factorial structure of the attitudes toward dissection as a school practice scale because of correlated items. Prior to the analyses, KMO (.912) and Barlett's test (Chi-Square = 2363,8; df = 66; sig < .001) were performed, with a scale falling into the range in which further analyses are permitted. Principal components with Eigenvectors above 1, and items with loadings above the 0.4 level are reported due to the breath of the reported findings; however, parallel analysis (Flora & Curran, 2004) was the preferred choice to explore the number of factors to be retained.

c) Correlations were checked as parts of analyses provided by Factorial and Regression procedures. Pearson's correlation coefficients were calculated; coefficients below the 0.05 level (two-tailed) were considered significant.

d) Regression analysis: Linear regression analysis was performed with the enter and case-wise deletion option; variables below the 0.05 level (two-tailed) were considered significant.

e) Effect size was used to examine differences in opinions by students' school level (between lower secondary and upper secondary school) and gender. With the next equation: $r = -\frac{z}{\sqrt{N}}$ was calculated Effect size; where Z = Kolmogorov - Smirnov Z and $\sqrt{N}$ = the square root of the sample size (Field, 2009, p. 550), and in the case of related data output of Wilcoxon's matched pair test.

Microsoft® Excel 2010 was used for data input. The analyses were performed with the SPSS 21® statistical package according to the procedures suggested by Field (2009).

Results

Students' dissection and their interest in it regarding school level and gender

The students had two tasks. The first was to mark if they had examined touched or dissected fresh mammalian organs during biology classes and, if they had, which organs. The second task was to mark whether they would like

to examine, touch, or dissect fresh mammalian organs and, if so, which organs. A list of seven mammalian organs regularly available to the teachers and the open-ended option 'other' were given (Table 1).

Table 1. *Frequency of students, who have examined, touched or dissected mammalian organs and their interest in such practice to be performed in biology classes (N = 483)*

Organ	In biology classes, we have examined, touched or dissected organs		For better understanding, I would like to examine, touch, or dissect organs		Difference (N2 – N1)
	Frequency (N1)	Percent	Frequency (N2)	Percent	Diff
bones	200	41.41	310	64.18	110
eyes	156	32.29	300	62.11	144
hearth	117	24.22	341	70.60	224
livers	117	24.22	262	54.24	145
kidneys	98	20.29	270	55.90	172
brains	79	16.36	333	68.94	254
stomach	44	9.11	254	52.58	210
other	16	3.31	28	5.79	12

From Table 1, we can recognise that bones and eyes are the most commonly dissected mammalian organs in Slovenian schools, while brains and livers were the least commonly dissected. Except for eyes, which are normally discarded in slaughterhouses, all other organs are easily obtainable in local supermarkets for human or animal consumption. However, students' 'wish list' about what should be examined differs significantly from what they actually do in a school in all cases, with heart and brains at the top, and no organ falling below the 50% margin.

We were not able to find any statistically significant differences on performance and opinions about dissection between genders, except for the field 'other' in the opinion part, where boys are more enthusiastic than girls with their proposals about organs to be added. Statistically significant differences are also present among lower and upper secondary students; however, differences expressed as effect sizes are almost non-existent and small, all falling below $r < .12$ levels. Differences in actual dissection between lower and upper secondary schools also exist, but do not exceed small or lower margin of medium levels, with the highest sizes for brains ($r = 0.2$) and bones and livers ($r = 0.4$).

Table 2. *Number of organs that students actually dissected and number of organs they would like to dissect*

Number of organs	In biology classes we have examined, touched, or dissected organs		For better understanding, I would like to examine, touch, or dissect organs	
	Frequency	Percent	Frequency	Percent
0	111	22.98	67	13.87
1	176	36.44	30	6.21
2	75	15.53	32	6.63
3	46	9.52	57	11.80
4	33	6.83	46	9.52
5	25	5.18	45	9.32
6	13	2.69	32	6.63
7	4	0.83	160	33.13
8	0	0.00	14	2.89
Total	**483**	**100.0**	**483**	**100.0**

From Table 2, we can recognise that about 23% of students from our sample had never examined, touched or dissected animal organs as laboratory work, and less than 10% had experiences with more than five organs. The statistical difference between elementary and secondary schools in the performance of actual dissection is insignificant ($U = 27958$; $p = .75$; $r = .01$).

However, only 13.9% of students declared that they would not like to examine, touch or dissect organs, and more than half (51.9%) declared that they would like to examine, touch or dissect more than five different organs. Prior to the study, we thought that practice would predict desired practice in negative or positive ways, but correlations between the sum of actually dissected organs from the list and organs that students would like to dissect practically do not exist ($r = -0.06$, $p = 0.20$). Differences between genders are statistically insignificant ($U = 27248.5$; $p = .38$; $r = .04$). Slightly larger, but marginally significant at $p < .01$ levels, are differences in the desire to dissect between elementary and secondary school students ($U = 25526$; $p = .05$; $r = .09$): elementary school students show slightly more enthusiasm for such activities.

Table 3. *Differences between the number of mammalian organs students actually dissected and the number of organs they would (dis)like to dissect*

Difference	Frequency	Percent
-8	2	0.41
-7	48	9.94
-6	64	13.25
-5	50	10.35
-4	53	10.97
-3	47	9.73
-2	47	9.73
-1	33	6.83
0	**61**	**12.63**
1	26	5.38
2	19	3.93
3	14	2.89
4	8	1.66
5	10	2.07
7	1	0.21
Total	**483**	**100.0**

Differences for individual students between what was actually dissected and what is on their wish list shows that only 12.6% of students (difference is 0) are satisfied with what happens in their biology classes. The negative values show that most of them (71.2%) would like to dissect more organs than they actually did, and only about 16.2% would like to dissect fewer. Differences between genders are not statistically significant ($U = 26945.5$; $p = .28$; $r = .05$), and between elementary and secondary schools as well ($U = 25889$; $p = .09$; $r = .08$) in favour of elementary schools.

Opinions about teaching and learning practices in which fresh mammalian materials are used

Results of opinions provided by elementary and secondary school students are provided in Table 4; differences between genders and school levels, calculated by Mann Whitney test, ranks, p-values and effect sizes are provided in the Appendix.

Table 4. *Opinions about teaching and learning practices in which fresh mammalian materials are used*

No	Statement	N	F1	F2	F3	F4	F5	M	SD	Me	Mod	PC1	PC2	PC3
14	Work with fresh materials should be included in lessons about the human body.	482	55 11.42	53 11.00	109 22.62	123 25.48	142 29.48	3.51	1.32	4	5	**.88**	-.08	.12
9	I would like to work with fresh materials more often.	482	60 12.45	58 12.03	96 19.92	105 21.78	163 33.82	3.52	1.39	4	5	**.85**	.00	-.00
3	When we work with fresh mammalian organs (brains, eyes, etc.) in biology lessons, it motivates me more for classroom cooperation and learning.	482	65 13.49	48 9.96	85 17.63	101 20.95	183 37.97	3.60	1.42	4	5	**.85**	-.02	.03
1	During anatomy and physiology lessons about the human body, I would like to examine, touch or dissect mammalian organs.	481	49 10.19	45 9.36	111 23.08	98 20.36	178 37.01	3.65	1.33	4	5	**.83**	-.03	.14
15	Because of work with fresh materials, I would more easily make a decision about a profession in medicine.	482	70 14.52	64 13.28	118 24.48	86 17.84	144 29.88	3.35	1.40	3	5	**.68**	-.09	.24
4	I do not like to work with fresh materials.	483	176 36.44	104 21.53	102 21.12	41 8.49	60 12.42	2.39	1.37	2 (4)	1 (5)	**.68**	.18	-.22
10	I prefer that a teacher show us a model or a picture of an organ than showing us a fresh one.	483	108 22.36	124 25.67	119 24.64	55 11.39	77 15.94	2.73	1.35	3 (3)	2 (4)	**.64**	.14	-.37
5	When I see fresh mammalian organs, I feel sick.	482	178 36.93	105 21.78	88 18.26	48 9.96	63 13.07	2.40	1.40	2 (4)	1 (5)	**.42**	.33	**-.40**
6	I cannot recognise a difference between learning from fresh material or plastic model of brains.	483	170 35.20	118 24.43	108 22.36	43 8.90	44 9.11	2.32	1.29	2 (4)	1 (5)	**.42**	.05	-.10
7	I do not like to learn about the human body.	482	219 45.44	114 23.65	88 18.26	38 7.88	23 4.77	2.03	1.18	2 (4)	1 (5)	.09	**.77**	.11
12	Processes inside our body that we cannot see are not important, so it is unnecessary to burden us with them.	482	250 51.87	94 19.50	93 19.29	22 4.56	23 4.78	1.91	1.15	1 (5)	1 (5)	-.13	**.87**	.07
8	I like themes that are connected to everyday life.	483	17 3.52	15 3.11	80 16.56	149 30.85	222 45.96	4.13	1.03	4	5	.17	.25	.83
	Cronbach's alpha											.89	.57	NA
	Variance explained											43.0	10.3	9.60
	Eigenvalue											5.17	1.23	1.15

Note: Results are sorted by decreasing values of Principal Components (PC1–PC3). Percentages are given below frequencies (F1–F5). Values in Values in brackets in Median (Me) and Modus (Mod) Columns are reverse coded.

Three principal components (Table 4) were extracted using eigenvalue > 1 criteria, but only one factor is retained. From the factor itself and frequencies of answers (items) composing it can be revealed that most of the students are

supportive toward the inclusion of fresh mammalian organs in their instructions. They recognise learning about human body and processes inside it as important and like themes connected to everyday life. Differences between genders (See Appendix), even if statistically significant, are expressed as effect size values, small, and exceed the .2 level in only one item, showing a greater interest of girls toward processes inside their body. Similarly, all differences in opinions between elementary and secondary school students fall below .15 margins. Small effect size values allow us to treat the whole sample as one group in our analyses.

Discussion

Dissection of mammalian organs is a preferred activity for the largest number of students, regardless of gender or school levels. These findings are in line with previous knowledge that practical and active work is what students missed the most in Slovenian biology education (Šorgo & Špernjak, 2007). However, many students do not have this opportunity, because a number of teachers rely on presentations, even if laboratory alternatives are available (Šorgo, Usak, Aydogdu, Keles & Ambrozic-Dolinsek, 2011); active methods, laboratory work included, is recommended by syllabi of science subjects (Šorgo & Špernjak, 2012). From the study, we cannot make definite conclusions about the reasons of teachers for the exclusion of dissections from their laboratory practices. Implicitly, for a number of teachers, the reasons are most probably a combination of overloaded curricula, preferred explanatory style of instructions, commodity, costs of fresh materials, and the safety of avoiding critiques or pressures from the minority of parents and opinion makers who are opponents of such practices. A study answering these questions is necessary.

From the presented results (Tables 1, 2, 3), we can conclude that only a minority of students (less than 15%) would potentially like to opt-out from dissection practice or perform it in an alternative way; most of the students would like to dissect more frequently. Statistical differences between genders and school levels are insignificant, so we can differentiate between them only on the basis of their abilities. This finding can be used as an incentive toward the introduction of more interesting and active teaching practices, dissection included, often absent from Slovenian science education (Ploj Virtič & Šorgo, 2016; Šorgo & Kocijančič, 2011; Šorgo & Špernjak, 2012).

Given that science is not one of the most popular subjects for a majority of students, the exclusion of dissection from laboratory work would sacrifice valuable teaching practice that can make it more interesting and appealing to them. Although we respect most of the arguments against dissection of animals

in a school classroom, we would not recommend discarding dissection, but would allow an opt-out scheme for the minority of them who would not like to perform or attend dissection, allowing them to fill missing knowledge gaps with alternative methods, such as virtual dissection, or learning from charts.

We do not support the killing of animals in elementary and secondary schools solely for the purpose of dissection. However, we strongly support a practice in which animals or their parts to be used as human or animal food are to be presented in a classroom to students as 'homes of life'. In such a way, arguments regarding the ethics of school dissection can be largely weakened on the basis of arguments that:

a) no animal was sacrificed for the purpose of dissection;
b) they have been slaughtered by professionals according to the existing standards for human consumption;
c) that the presentation of animal organs to the students can not present a greater stress than that of walking through the meat department in supermarkets;
d) that stress from dissection cannot exceed that experienced by home meat preparation for consumption;
e) and last and not least that no part of dissected organs will be discarded, but used to feed other animals, such as lizards, frogs and fish in school aquaria and terraria, or domestic animals, such as dogs and cats.

Dissection as a teaching practice can raise interest in biology, competing with the falling interest in science worldwide among adolescents. The results from our study on attitudes (See Table 4) are similar to findings that dissection is a preferred method of anatomy laboratories at college levels (Lombardi, Hicks, Thompson & Marbach-Ad, 2014). Osenkowski, Green, Tjaden and Cunniff (2015) also reports students' great interest in dissection and that this is the reason that educators still use it, although they would like to exchange dissection with alternatives. According to Lombardi et al. (2014), plastic models may be more effective than organ dissections or virtual dissections for teaching heart anatomy and physiology content, but organ dissections may have the highest perceived practical value and may be superior for improving students' attitudes toward science. In classrooms, a variety of hands-on (including dissection) and model-assisted activities should be used, as this may accommodate students of varied learning styles, and different activities are best suited to achieving different goals. Holstermann et al. (2009) claimed that topics that relate to aspects of human biology are of interest to students, which is confirmed by this study: students like to learn about anatomy and physiology of

the human body, which is connected to everyday life. Holstermann et al. (2009) also investigated students' disgust and interest in dissection; the results show that dissection has a high potential to influence students' intrinsic motivation positively if the students do not feel disgust. This empirical evidence might be an important argument to justify – and improve – dissection in biology classes.

Differences between genders are present in our study, but are, according to calculated effect sizes, small or even non-existent, and cannot affect teaching. Some studies in the effects of dissection-room experiences in medical schools have also found no gender differences of the impact of dissection (Bernhardt, Rothkötter & Kasten, 2012), while several others have reported higher levels of stress among women than men (Bernhardt et al., 2012; Dempster, Black, McCorry & Wilson, 2006). Bernhardt et al. (2012) thought that this may have been due to women being more prepared than men are to admit and divulge their own emotional reactions.

Conclusions

Based on our results, we can make some conclusions and recommendations to improve biology instruction, to make it more interesting and more effective.

Even if there are many studies arguing that knowledge on anatomy and physiology can be achieved by virtual methods, or using 3D models, we can argue that a number of studies shows that combinations of hands-on models, and virtual activities should be the preferred choice. Dissection of organs is important for several reasons: students can make a connection between theory and practice; they can feel the structures of organs, observe organs in real size and real colour; observe the inner structures of organs like cardiac valves in the heart or the whiteness and greyness of brain, they can make experiments with the eye lens and observe retina, determine the significance of the cornea strength, determine the flexibility and hardiness of bones, and observe the stomach structure and kidneys. According to Mayer (2007), dissection contributes to more adequate epistemological beliefs. It is also a scientific hands-on activity that develops students' manual skills.

As a final conclusion, we can advise teachers, contributors, and authors of the Slovenian biology syllabi (curricula) that even if dissection is rare in Slovenian biology classes, and some ethical concerns on dissection may exist, this practice should be encouraged. Because of students' interest, and to provide students with the best alternatives toward study of 'homes of their lives', we should encourage dissection together with models and computer simulations

to make the learning process more effective and interesting. For those who do not wish to participate in dissection, opt-out option should be provided.

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Appendix

Differences between genders and school levels, calculated by Mann Whitney test, ranks, p-values and effect sizes.

	Gender	Mean Rank	U	p	r	School	Mean Rank	U	p	r
During anatomy and physiology lessons about the human body, I would like to examine, touch, or dissect mammalian organs.	m	234.50	26986	.32	.05	1	258.83	24799	.02	.11
	f	246.72				2	228.89			
When we work with fresh mammalian organs (brains, eyes, etc.) in biology lessons, it motivates me more for classroom cooperation and learning.	m	244.53	28042	.72	.02	1	265.66	23617	.00	.15
	f	240.10				2	224.85			
I do not like to work with fresh materials.	m	253.09	26271	.12	.07	1	262.79	24200	.00	.13
	f	233.68				2	226.93			
When I see fresh mammalian organs, I feel sick.	m	269.54	22865	.00	.18	1	264.02	23950	.00	.14
	f	221.34				2	226.04			
I cannot recognize a difference between learning from the fresh or plastic models of brains.	m	225.11	25069	.03	.11	1	246.98	27409	.49	.03
	f	254.67				2	238.39			
I do not like to learn about the human body.	m	233.74	26856	.23	.05	1	249.12	26974	.31	.01
	f	248.20				2	236.84			
I like themes that are connected to everyday life.	m	222.67	24564	.015	.13	1	264.31	23892	.00	.15
	f	256.50				2	225.83			
I would like to work with fresh materials more often.	m	245.78	27783	.60	.02	1	263.09	24138	.00	.13
	f	239.16				2	226.71			
I prefer that a teacher show us a model or a picture of an organ than showing us a fresh one.	m	256.75	25513	.049	.09	1	263.25	24106	.00	.13
	f	230.94				2	226.59			
Processes inside our body that we cannot see are not important, so it is unnecessary to burden us with them.	m	208.62	21656	.00	.23	1	255.75	25629	.05	.09
	f	267.03				2	232.03			
Work with fresh materials should be included in lessons about the human body.	m	243.13	28332	.87	.01	1	266.36	23475	.00	.15
	f	241.15				2	224.34			
Because of work with fresh materials, I would more easily make a decision about a profession in medicine.	m	247.35	27458	.45	.03	1	253.64	26057	.11	.07
	f	237.99				2	233.56			

Note: In all items, except in item 1 (N = 482) total number of responses is 483. Number of males is 207 (206), and females 276; number of elementary school students is 203, and secondary school students 280 (279).

Assessment Accommodations for Foreign Pupils in the Light of Educational Justice: Empirical Research among Slovenian Primary School Teachers

Mojca Žveglič Mihelič[1]

The starting points of primary school pupils in a foreign country differ significantly from those of native pupils. In Slovenia, the knowledge of pupils who are foreign citizens (foreign pupils) may be assessed with different accommodations for no more than two years. The presented research conducted on a representative sample of 697 Slovenian primary school teachers addresses their perspectives, using a questionnaire, on assessment accommodations for foreign pupils. The following research questions are answered: 1) What are teachers' perceptions of assessment accommodations for foreign pupils; are there differences between teachers who had recently taught foreign pupils and those who had not? 2) Do generalist teachers have different perceptions than subject teachers do? 3) What kind of assessment accommodations do teachers practice for these pupils after the expiration of the two-year period; do generalist and subject teachers act differently? 4) Do teachers perceive assessment accommodations as being just? We demonstrate that teachers who have recent experience of teaching foreign pupils are more aware of the need for assessment accommodations than those who do not. The majority of the teachers accommodate assessment and grading even after the two-year period, especially generalist teachers. Additionally, some of them have lower expectations with regard to achieving knowledge standards for these pupils. While the majority of the teachers perceive accommodated assessment as being just, they are unsure of whether the period of allowed adjustments should be longer. This raises the questions about teachers' understanding of educational justice and the application of the principle of justice in practice.

Keywords: assessment accommodations;, educational assessment and grading; justice in education; primary school teachers; pupils without Slovenian citizenship

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Prilagajanje preverjanja in ocenjevanja znanja učencev tujcev z vidika šolske pravičnosti: izsledki raziskave med slovenskimi osnovnošolskimi učitelji

Mojca Žveglič Mihelič

Izhodišča osnovnošolcev, ki so tuji državljani, se pomembno razlikujejo od izhodišč učencev, ki so slovenski državljani. Preverjanje in ocenjevanje znanja učencev, ki so tuji državljani (učenci tujci), se v Sloveniji lahko izvaja z različnimi prilagoditvami, a največ dve leti od vpisa učenca v slovensko osnovno šolo. V tem prispevku predstavljamo izsledke empirične raziskave, v kateri smo anketirali reprezentativni vzorec 697 slovenskih osnovnošolskih učiteljev glede njihovega pogleda na prilagoditve preverjanja in ocenjevanja znanja učencev tujcev. Odgovarjamo na naslednja raziskovalna vprašanja: 1) kakšna so stališča učiteljev o prilagoditvah preverjanja in ocenjevanja znanja učencev tujcev in ali se glede tega pojavljajo razlike med učitelji, ki poučujejo učence tujce, ter tistimi, ki poučujejo le slovenske državljane; 2) ali se stališča učiteljev razrednega pouka o prilagoditvah preverjanja in ocenjevanja znanja učencev tujcev razlikujejo od stališč učiteljev predmetnega pouka; 3) katere prilagoditve preverjanja in ocenjevanja znanja učencev tujcev učitelji izvajajo po preteku dveletnega obdobja, ko so posamezne prilagoditve preverjanja in ocenjevanja dovoljene, in ali se pojavljajo razlike med učitelji razrednega ter učitelji predmetnega pouka; 4) kakšno je mnenje učiteljev glede pravičnosti prilagojenega preverjanja in ocenjevanja znanja učencev tujcev. Izsledki raziskave so pokazali, da učitelji, ki so med raziskavo poučevali tudi učence tujce, potrebo po prilagoditvah preverjanja in ocenjevanja znanja teh učencev prepoznavajo v večji meri kot učitelji, ki učencev tujcev med raziskavo niso poučevali. Ugotovili smo, da večina učiteljev, še zlasti učiteljev razrednega pouka, preverjanje in ocenjevanje znanja omenjenih učencev prilagojeno izvaja tudi po preteku uradno določenega dveletnega obdobja. Prilagoditve, ki jih izvajajo nekateri učitelji, pa obsegajo tudi zniževanje zahtevnosti meril ocenjevanja teh učencev. Večina učiteljev prilagojeno ocenjevanje označuje kot pravično, medtem ko so mnenja učiteljev o tem, ali bi bilo treba obdobje dovoljenih prilagoditev preverjanja in ocenjevanja znanja učencev tujcev podaljšati, deljena. Izsledki raziskave s tem odpirajo vprašanje o pojmovanju pravičnosti v izobraževanju med učitelji in aplikacijo načela pravičnosti v šolski praksi.

Ključne besede: prilagoditve preverjanja in ocenjevanja znanja, preverjanje in ocenjevanje znanja, pravičnost v izobraževanju, osnovnošolski učenci, učenci brez slovenskega državljanstva

Introduction

Pupils without Slovenian citizenship who enrol in a Slovenian primary school[2] cope with many difficulties before achieving parity with their Slovenian classmates (i.e. pupils with Slovenian citizenship). They face a different environment from their own, a different language and a different education system with its own particularities. However, it is not only the starting point of a foreign pupil that is very different from that of a native Slovenian pupil. The results of the international study PISA (Programme for International Student Assessment) in 2009 show that the performance of immigrant pupils is incomparable with that of native pupils, especially in countries where native pupils perform exceptionally well and where foreigners do not speak the language of instruction at home (Šori, Šušterič, & Gaber, 2011).[3] Šori and colleagues claim that immigrant pupils 'do not gain the same benefits from the educational system' (ibid., p. 37). According to other secondary studies of the PISA results, this is obviously not a new trend. The results of a secondary study of PISA 2003 data, conducted by Levels and Dronkers (2008), implicate similar positions of migrant pupils in general. Their analysis included Australia, Austria, Belgium, Denmark, Germany, Greece, Ireland, Latvia, Liechtenstein, Luxembourg, New Zealand, Switzerland, and Scotland. The results of their study of the extent to which native and first- and second-generation migrants from various regions of origin, living in thirteen different countries of destination, differ in their scholastic ability showed that both the origin and destination of migration have significant effects on educational achievement, and that these effects play an important part in explaining differences in educational achievement between all three types of pupils. The authors claim that cross-national differences in these pupils' educational performance might be 'partly explained by different educational systems, by different policy measures concerning the reduction of socio-economic inequalities or by different immigration laws' (ibid., p. 1406). The research conducted by Scott, Webber, Lupart, Aitken, and Scott (2014) among Canadian educators showed that almost 60% of them perceived that students' cultural background affected the grades these students received.

2 Compulsory basic education in Slovenia is organised in a single structure nine-year basic school attended by children aged six to fifteen. Generalist teachers teach in the first five grades, and in some cases also in the sixth grade, while subject teachers teach pupils from the fourth to the ninth grade.

3 Immigrant pupils in this context are either first generation ('those born outside the country of assessment and whose parents were also born in another country') or second generation ('those born in the country of assessment but whose parents were born in another country') (OECD, 2010, p. 170). Therefore, pupils we regard as pupils without Slovenian citizenship are included in the wider group of immigrant pupils, and we assume that they face even greater challenges in the Slovenian education system than other pupils who fit the definition of immigrant pupils due to the language barriers and cultural differences they face.

For an education system to be just, it is important to take the obstacles faced by pupils without the citizenship of the country of residence into consideration in education legislation and in educational practice. Some authors even express the need for the expansion of conceptualisation of special needs due to cultural, linguistic, and religious differences among pupils in the West (Scott et al., 2014; Webber & Lupart, 2011).

According to the *Elementary School Act* (2006), pupils who are foreign citizens residing in the Republic of Slovenia are entitled to compulsory basic education on the same terms as Slovenian citizens. Additionally, they are offered adjustments that help them cope with instruction in a new language and cultural setting. Upon entering primary education, pupils who are Slovenian residents and whose mother tongue not Slovenian receive Slovenian language classes as well as instruction in their mother tongue in cooperation with the country of their origin. As far as assessment of knowledge is concerned, the *Rules on Knowledge Assessment and Grading and Students' Progress to a Higher Class Standing in Elementary Schools* (2013) define the right of a pupil without Slovenian citizenship to different assessment accommodations during a two-year period starting with their enrolment in a Slovenian school. During this period, the knowledge of these pupils is assessed differently than that of pupils with Slovenian citizenship. Assessment accommodations, such as selection of assessment methods, number of examination periods, grades, etc., are chosen by the teachers' assembly at the school.

The present paper deals with assessment accommodations for pupils without Slovenian citizenship in the light of educational justice. For this reason, we asked primary school teachers in Slovenia about their perspectives on assessment accommodations for pupils without Slovenian citizenship, whether they accommodate the assessment and grading process for those pupils after the expiration of the allowed period of two years from enrolling in a Slovenian primary school, what kind of assessment accommodations they use, and whether they perceive the accommodations as being just or not.

Justice in Education

The conception of justice is traditionally bound to two basic notions that are presented by Aristotle in his work *Nicomachean Ethics*: 'the just as the lawful (universal justice) and the just as the fair and equal (particular justice)' (Aristotle, 2009 version, p. 80). In the first case, justice is paralleled with legality, so

an act is just when it is in accordance with the law.[4] The second notion defines a just act or a just law in the context of establishing or maintaining fairness of treatment. According to Aristotle, justice represents a virtue with two forms: the form of distributive justice and the form of rectificatory justice. In both cases, a just act is formally defined. Distributive justice concerns the fair distribution of wealth and other goods among the members of a certain community with regard to their individual merits. Rectificatory justice is, in contrast, concerned with the reestablishment of the position of a person before certain harm was inflicted on that person, who was therefore treated unjustly (ibid). Cicero's principle of distributive justice (*to each his own*) is connected to a law that defines what is theirs. This definition of justice is known as the fundamental definition of justice. Due to criticism of the definition of distributive justice with regard to the question what is *theirs*, different theories of justice suggest different principal criteria for deciding what is and what is not just. These criteria are: to each according to one's merits, to each according to one's abilities, to each according to one's works, or to each according to one's efforts. All these criteria are, however, bound to the concept of formal justice according to which the same beings must be treated in the same way, and different in a different way (Kodelja, 2006).[5] According to Perelman (1963), individuals who are equal according to the chosen criteria must be treated in the same way. Because individuals are unequal in whichever characteristic we choose as the criterion, one has to form groups of individuals with the same level of the chosen characteristic and treat them equally within each group. This means that one has to apply the same rule for all of the individuals within a group. In the case of knowledge assessment, the same grades are thus given to the pupils who demonstrate the same level of knowledge. As formal justice does not define the criteria essential for the administration of justice but only sets the rule of its practical use, it is also called justice in application (Bobbio, 1995; Perelman, 1963).

Problems arise when two criteria for the administration of justice are being used. If one assesses the level of knowledge as well as the amount of effort invested in learning, and then two pupils demonstrate the same level of knowledge while investing a different amount of effort in their learning, it is not clear

4 Despite the definition of a just act as a legal act, and therefore an unjust act as an illegal act, Aristotle (2009 version) allows the possibility of the law itself being unjust. This may occur in a situation where an act is in accordance with the law but is at the same time inappropriate in terms of justice due to the universality of the law. In this case, the injustice of the law must be replaced by equity. According to Aristotle, 'the equitable is just, but not the legally just but a correction of legal justice' (ibid., pp. 98–99).

5 Perelman (1963) adds a few other criteria or conceptions of justice: to each the same thing, to each according to one's needs, to each according to one's rank, and to each according to one's legal entitlement.

which grade they should receive. The reason for the confusion lies in the fact that the criteria *to each according to one's works* and *to each according to one's efforts* are being applied at the same time. If one followed the first criterion, both pupils would receive the same grade, but this would not be in accordance with the concept of formal justice because the second criterion requires taking into account the amount of effort invested in learning. If, in contrast, one did not give the pupils the same grade, the treatment would be unjust due to unequal treatment required by the first criterion (Kodelja, 2006). According to Perelman (1963), priority should be given to one essential characteristic (in our case knowledge or effort) at the expense of all the others. The essential characteristic is to be given the first consideration, while 'the rest [are] allowed to exert their influence only in so far as the primary one is not thereby disturbed' (ibid., p. 31).

Equality of Opportunity in Education

In socially and economically developed countries where the quantity of goods is limited, formal justice is manifested according to the principle of equality of opportunity. Besides providing equality of accessibility to education, the principle of equality of opportunity in education also includes the provision of equality of starting points in the educational process. These two conceptions of equality of opportunity are heterogeneous, as equality of accessibility of education is associated with a form, while equality of starting points is bound to material conditions and circumstances (Kodelja, 2006). Additionally, the principle of equality of accessibility forbids discrimination, while the principle of equality of starting points requires it. Measures for equalising pupils' starting points, in the sense of privileging the unprivileged (i.e., positive discrimination), are a means of equalisation of individuals' starting points. In this case, therefore, the inequality established by these measures is a means of achieving equality (Bobbio, 1995). Although positive discrimination policies particularly accentuate the need for implementing measures to nullify, or at least reduce inequalities in the starting points and results of underprivileged minorities, pupils without Slovenian citizenship find themselves in a similarly unequal position when enrolling in a Slovenian school, especially due to the linguistic and cultural differences they have to cope with.

Injustice in education is therefore connected to intentional or unintentional ignorance of the differences between pupils that are not a result of their work, invested effort, motivation, etc., but originate from the unequal natural distribution of abilities and talents, and from social inequalities that are beyond the pupil's control. Rawls's conception of justice as 'the first virtue of social

institutions' (Rawls, 1999, p. 3) offers a solution for the unjust treatment of individuals or groups who are in an underprivileged position due to their ethnic, cultural or social origin. He defines two principles of justice for institutions:

> First principle: Each person is to have an equal right to the most extensive total system of equal basic liberties compatible with a similar system of liberty for all.
>
> Second principle: Social and economic inequalities are to be arranged so that they are both:
>
> a) to the greatest benefit of the least advantaged, consistent with the just savings principle, and
> b) attached to offices and positions open to all under conditions of fair equality of opportunity. (ibid., p. 266)[6]

The principle of fair equality of opportunity differs from the principle of formal equality of opportunity, which eliminates only legal obstacles in achieving certain social position or education. The essence of fair equality of opportunity lies in enabling the individual to genuinely achieve this social position or education. With regard to the unequal distribution of natural predispositions among individuals, those with equal abilities and talents should have equal opportunities for success despite the differences in their initial social status. However, equal abilities and talents are not the only factors of an individual's social success or academic achievement. A willingness to use these abilities, as well as aspirations and a capacity to gain from education, are also key factors in social success, and these factors have little to do with the biological dispositions of individuals. According to Rawls, these factors are primarily associated with a variety of social conditions that may present barriers to equal opportunities between individuals (ibid.). The author concludes that social inequalities should be corrected, while inequalities in the proved abilities and effort invested should be in favour of the most disadvantaged. As social inequalities can only be overcome to a certain extent, and given the fact that it is usually difficult to define exactly whether a certain inequality originates from social, biological, or individual inequalities, Meuret (2001) presents two solutions to this problem: one proposed by Walzer and the other by Rawls. Walzer suggests defining two phases of schooling. During the first phase (the elementary phase), the aim is to

6 The two principles are systematically ordered so that the first principle has priority over the second. The first priority rule claims that '(a) a less extensive liberty must strengthen the total system of liberties shared by all; (b) a less than equal liberty must be acceptable to those with the lesser liberty' (Rawls, 1999, p. 266). In contrast, the second principle of justice is lexically prior to the principle of efficiency and to the principle of maximising the sum of advantages, while fair equality of opportunity is prior to the difference principle.

compensate for social and natural handicaps, as well as for differences in pupils' desire to learn. Thus, the goal of this phase is equality of results, which means one helps each child to master the same body of knowledge. Consequently, not all children are treated equally in the same way. The second phase (secondary education and schooling above the secondary level), in contrast, aims at enabling individuals to obtain as much education as their abilities allow. Rawls's solution is to apply an additional principle to the principle of fair equality of opportunity, i.e., the difference principle. According to this principle, 'an inequality of opportunity must enhance the opportunities of those with the lesser opportunity' (Rawls, 1999, p. 266).

According to Kodelja (2006), one of the basic rules of justice in education is the provision of knowledge assessment and progression in the education system on equal terms for everyone. Assessment is thus just when the grade received is equivalent to the knowledge demonstrated. It would, therefore, be unjust if a pupil who failed to achieve the educational standards progressed to another grade with others who did achieve these standards. However, it is equally unjust if one ignores the unequal starting points of pupils, for which they are not at fault, and provides equal opportunities on a formal level only. For Medveš (2002), this would not only imply injustice because of advancement under different terms, but also cause the school to take on less responsibility for the knowledge and potential development of such pupils.

Slovenian regulations on educational assessment in primary school consider both the principle of fair equality of opportunity and the difference principle. In the *Rules on Knowledge Assessment and Grading and Students' Progress to a Higher Class Standing in Elementary Schools* (2013), it is stated that, in agreement with parents, schools may accommodate the assessment and grading of a foreign pupil for as long as two years after the enrolment of the pupil in a Slovenian school. It is claimed that in this period a foreign pupil would overcome the differences (for the most part linguistic) that put him/her in an unequal starting position with regard to the other, native pupils. Accommodated assessment for pupils without Slovenian citizenship thus represents a means of positive discrimination in a broader sense. These pupils are in an underprivileged position, especially with regard to the language of instruction, so according to the principle of fair equality of opportunity, a kind of compensatory education is provided for them. The *Act Amending the Elementary School Act* (2011) establishes:

> Children who reside in the Republic of Slovenia and do not speak Slovenian as their first language, […] upon enrolment in primary school receive organised tuition in the Slovenian language and culture as well

as tuition in their first language and their culture of origin in accordance with international treaties. (Article 1)

One may conclude that, according to legal provisions, the accommodation of treatment of pupils without Slovenian citizenship after the expiration of the allowed period of two years should be limited to the accommodations required by internal differentiation and individualisation due to individual differences between pupils. However, what are pupils', parents' and teachers' understandings of justice in education? According to the results of research conducted among French pupils, knowledge assessment is just when pupils who demonstrate the same level of knowledge receive the same grade (Kodelja, 2006). Similarly, research on Slovenian teachers' and parents' opinions on justice in assessment indicates that the majority of both teachers and parents are convinced that only knowledge should be included in assessment (Kovač Šebart & Krek, 2009). In summary, the results of these studies show that in the opinion of pupils, teachers and parents 'it is necessary to respect an objective network of assessment that forms a clear, transparent measure and a precise procedure of measuring' (ibid., p. 203). These findings represent the basis for the present research conducted among Slovenian primary school teachers, the results of which are presented in the next part of the paper.

Subject of the research

The research addresses Slovenian primary school teachers' perspectives on assessment accommodations for pupils without Slovenian citizenship (mostly from former Yugoslav republics) and the assessment accommodations they practice for these pupils after the expiration of the legally defined period for different assessment accommodations.

The reason the research has been conducted with primary school teachers is that the accommodations of the assessment are only permitted by law in the primary schools. The following research questions are answered:

1. What are teachers' perceptions of assessment accommodations for foreign pupils; are there differences between teachers who had recently taught foreign pupils and those who had not? We aimed to determine whether the perceptions of teachers who had taught at least one pupil without Slovenian citizenship in the 2011/2012 school year (foreign pupils' teachers) are somewhat different from those of teachers who had taught only pupils with Slovenian citizenship (Slovenian pupils' teachers).

2. Do generalist teachers have different perceptions than subject teachers?
3. What kind of assessment accommodations do teachers practice for these pupils after the expiration of the two-year period; do generalist and subject teachers act differently?
4. Do teachers perceive assessment accommodations as being just?

Methodology

Sample: The research was conducted on a representative sample of Slovenian primary school teachers in June 2012. It included generalist teachers and subject teachers from 79 primary schools in Slovenia. The schools were selected on the basis of region and size, which means that schools from all of the Slovenian regions were included, ensuring that schools from urban and rural environments were represented equally, as were larger and smaller schools. Completed questionnaires were returned by 301 generalist teachers and 396 subject teachers, from 76.0% of the primary schools included in the research. A detailed description of the sample is presented below.

In terms of gender, 88.3% of the sample is represented by women and 11.7% by men. Their average age was 42.67 years (SD = 8.68 years), and they had 18.69 years of work experience (SD = 10.36 years). The largest proportion of the teachers had a university degree (62.9%), while a third had a short-cycle college degree (32.3%), 3.3% had finished professional college, 1.4% had a post-graduate degree, and 0.2% had completed four-year upper-secondary school. With regard to the seniority of the teachers within the Slovenian public school system, 15.7% of our sample were among the lowest-ranking teachers, 34.3% had 1st degree promotions, 44.8% had 2nd degree promotions, and 5.2% had 3rd degree promotions. A quarter of the generalist teachers taught in the first grade (25.1%), a fifth in the third grade (21.9%), 17.9% in the second grade and the same share in the fourth grade, while 16.7% of the generalist teachers taught in the fifth grade and 0.4% in the sixth grade. Amongst the subject teachers, more than half taught in the second and third cycles (55.5%), 34.9% only in the third cycle, and 4.8% in all three cycles. The smallest shares of the subject teachers taught in the first and second cycles (2.4%) or only in the second cycle (2.1%). A quarter of all of the teachers in the sample (25.5%) taught at least one pupil without Slovenian citizenship in the 2011/2012 school year. Of these teachers, 62 were generalist teachers and 116 were subject teachers.

Instruments: The data were collected through two similar questionnaires (one for generalist teachers and one for subject teachers), which were prepared for the present research. The questions are tackling teachers' perceptions on different

assessment accommodations and the elements they accommodate for pupils without Slovenian citizenship after the expiration of the legally defined period. A general question of whether they perceive the accommodated assessment and grading process for those pupils as just was posed as well as questions about their sex, age, number of years of teaching, level of education, grade they taught in (in the questionnaire for generalist teachers), subject they taught (in the questionnaire for generalist teachers), and number of pupils without Slovenian citizenship they taught. The questions were formulated on the basis of formal regulations regarding assessment accommodations for pupils without Slovenian citizenship (Act Amending the Elementary School Act, 2011; Rules on Knowledge Assessment and Grading and Students' Progress to a Higher Class Standing in Elementary Schools, 2013).

Data Collection and Analysis: A different number of questionnaires were sent to each of the selected schools, according to the number of classes of the same grade. The principals of the schools were asked to distribute the questionnaires to the teachers according to the alphabetical order of their last names.

The data were analysed using SPSS (21.0). They were treated on the level of descriptive and inferential statistics, using the frequency distribution of the attributive variables, basic descriptive statistics of the numerical variables, and the Pearson chi-square test.

Results and Discussion: The aim was to determine the teachers' perceptions of the types and duration of accommodated assessment for pupils without Slovenian citizenship in a Slovenian primary school. We therefore tested the differences in perceptions of foreign pupils' teachers and Slovenian pupils' teachers regarding six statements.

Statistically significant differences between foreign pupils' teachers and Slovenian pupils' teachers emerged in opinions concerning statement *The knowledge of pupils without Slovenian citizenship and with a lack of Slovenian language knowledge should be assessed based on milder criteria than the knowledge of their Slovenian classmates*, with $\chi^2(2) = 13.338$, $p < 0.001$. Almost two thirds of foreign pupils' teachers (71.4%) and more than half of Slovenian pupils' teachers (57.0%) agreed with the statement. The share of those foreign pupils' teachers who did not agree with the statement was slightly smaller than that of Slovenian pupils' teachers (17.7% vs. 20.5%), while the share of those who were undecided was higher among Slovenian pupils' teachers (22.5%) than among foreign pupils' teachers (10.9%).

Opinions on the statement *Knowledge assessment of pupils without Slovenian citizenship may be performed using accommodated assessment methods* did not differ significantly between foreign pupils' teachers and Slovenian pupils' teachers. The majority of both groups of teachers agreed with the statement

(88.7% vs. 84.3%), while slightly more than 5% did not agree with it (5.6% vs. 5.1%). The share of undecided respondents was slightly higher amongst Slovenian pupils' teachers (10.6%) than foreign pupils' teachers (5.6%).

Both groups of teachers also had similar opinions on the statement *If necessary, dates of assessment may be adjusted for pupils without Slovenian citizenship*. The majority of foreign pupils' teachers (79.2%) as well as Slovenian pupils' teachers (71.5%) agreed with the statement, while less than a fifth of the teachers did not agree with it (13.5% vs. 16.4%). Again, the share of undecided is somewhat larger among Slovenian pupils' teachers (12.1%) than among foreign pupils' teachers (7.3%); however, the differences were not significant.

In contrast, significant differences emerged in the opinions of both groups of teachers regarding the statement *The number of grades may be adjusted for pupils without Slovenian citizenship*, with $\chi^2(2) = 14.861$, $p < 0.001$. A higher share of foreign pupils' teachers agreed with the statement than Slovenian pupils' teachers (69.7% vs. 53.4%). Additionally, a quarter of Slovenian pupils' teachers disagreed with the statement (25.3%), while the share of foreign pupils' teachers was smaller (19.7%). A larger share of Slovenian pupils' teachers was undecided (21.3%) than foreign pupils' teachers (10.7%).

The opinions of both groups of teachers on the statement *The determined period of allowed assessment accommodations for pupils without Slovenian citizenship should be longer than the currently allowed period of two years from their enrolment in a Slovenian primary school* were similar. Approximately a third of foreign pupils' teachers agreed with the statement (34.5%), while a third did not agree (33.3%) and another third was undecided (32.2%). Among Slovenian pupils' teachers, roughly a third agreed with the statement (36.8%), while a quarter did not agree (25.9%) and the largest share was undecided (37.3%). The differences in answers were, however, insignificant.

Differences between the opinions of foreign pupils' teachers and Slovenian pupils' teachers regarding the statement *The teaching process should be the same for pupils without Slovenian citizenship as for pupils with Slovenian citizenship from the beginning of their schooling* proved to be significant: $\chi^2(2) = 11.391$, $p < 0.05$. While the shares of teachers who agreed with the statement were similar among foreign pupils' teachers (19.1%) and Slovenian pupils' teachers (20.6%), the shares of those who disagreed with the statement were different (66.3% among the first group and 53.0% among the second group). Again in this case, the share of undecided was larger among Slovenian pupils' teachers (26.4%) than among foreign pupils' teachers (14.6%).

Within the group of foreign pupils' teachers, the opinions of generalist teachers were also compared with those of subject teachers regarding each of

the six statements, but the differences proved to be insignificant for all of the statements.

Additionally, we wanted to determine whether foreign pupils' teachers accommodate assessment and grading after the allowed period of two years from the enrolment of a foreign pupil in a Slovenian school, and if so how. *Table 1* contains the numbers and the shares of positive answers to different statements for all of the foreign pupils' teachers, and for generalist teachers and subject teachers separately.

Table 1. *The number of foreign pupils' teachers who agree with the statements related to accommodated assessment of pupils without Slovenian citizenship after the expiration of the legally allowed period*

Statements	Generalist teachers (*n* = 62)		Subject teachers (*n* = 116)		All teachers (*n* = 178)	
	f	f %	f	f %	f	f %
I do not accommodate the assessment and grading process after the expiration of the allowed period.	22	35.5	63	54.3	85	47.8
I accommodate methods of assessment.	27	43.5	30	25.9	57	32.0
I accommodate dates of assessment.	9	14.5	23	19.8	32	18.0
I accommodate the number of grades.	9	14.5	6	5.2	15	8.4
Other.	14	22.6	9	7.8	23	12.9

The largest share of foreign pupils' teachers stated that they did not accommodate the assessment and grading process after the expiration of the allowed period (47.8%). However, almost a third of the respondents stated that they did continue to accommodate the methods of assessment (32.0%), the majority of them indicating that they preferred to use oral examination rather than tests. Almost a fifth of the teachers indicated that they accommodated dates of assessment according to an agreement with the pupil, a performed announced assessment of knowledge, or extended deadlines for projects, seminars, etc. (18.0%). Some teachers also stated that they accommodated the number of grades for pupils without Slovenian citizenship (8.4%), explaining that these pupils get less grades than other pupils, especially in cases where the grades are based on tests. Additionally, a few teachers indicated that they also combined several grades into one, in order to motivate pupils for future learning. The majority of the teachers who stated that they performed other accommodations of assessment (12.9%) indicated that they usually accommodated assessment

criteria (i.e., lowering the expectations regarding the achievement of learning standards) or applied different accommodations according to individual foreign pupil's needs.

A comparison of the generalist teachers' answers with those of the subject teachers showed significant differences in statements regarding not accommodating the assessment and grading process for pupils without Slovenian citizenship after the expiration of the allowed period: $\chi^2(1) = 5.740$, $p < 0.05$. While the greatest share of subject teachers agreed with the statement, only a third of generalist teachers concurred, which leads to the conclusion that two thirds of the generalist teachers did in fact accommodate the assessment and grading process for pupils without Slovenian citizenship after the expiration of the allowed period. Significant differences also emerged in agreement with the statements about accommodating methods of assessment ($\chi^2(1) = 5.806$, $p < 0.05$) and the number of grades ($\chi^2(1) = 4.571$, $p < 0.05$). In both cases, a larger share of generalist teachers than subject teachers practised these accommodations. Furthermore, a greater number of generalist teachers than subject teachers stated that they lowered expectations regarding the achievement of learning standards with $\chi^2(1) = 5.809$, $p < 0.05$. Finally, the differences in statements regarding the accommodation of dates of assessments were statistically insignificant, as was the association between the level of education and the use of different assessment accommodations after the expiration of the allowed period.

The final question of the questionnaire was whether teachers perceived the accommodated assessment and grading process for pupils without Slovenian citizenship as just. The vast majority of foreign pupils' teachers as well as Slovenian pupils' teachers stated that such assessment was just (85.9% vs. 89.0%). The differences in the opinions between generalist teachers and subject teachers of pupils without Slovenian citizenship were statistically insignificant, as was the association between the opinion and the level of the teacher's education.

Conclusion

The results indicate that the majority of both foreign pupils' teachers as well as Slovenian pupils' teachers concur with using lower criteria in assessing and grading the knowledge of pupils without Slovenian citizenship, although the share of foreign pupils' teachers appeared to be significantly higher than the share of Slovenian pupils' teachers. The results are highly similar regarding accommodation of the number of grades and overall agreement with the necessity of a different approach to the treatment of pupils without Slovenian

citizenship compared to their Slovenian classmates in the educational process. In both cases, a larger share of foreign pupils' teachers than Slovenian pupils' teachers agreed with such treatment. Although the majority of teachers agreed with the accommodation of assessment methods and examination periods for pupils without Slovenian citizenship, they were not certain whether or not the duration of the normatively prescribed period of possible assessment accommodations should change. These results, as well as the fact that the differences in opinions between generalist teachers and subject teachers appeared to be statistically insignificant, lead us to the conclusion that teachers who have recent experience of teaching at least one pupil without Slovenian citizenship are more aware of the need for accommodations in the assessment of these pupils than teachers who have not.

As far as the use of assessment accommodations in practice is concerned, more than half of the foreign pupils' teachers stated that they did in fact practice various assessment accommodations after the expiration of the allowed period. For all of the accommodations, however, the share of generalist teachers was significantly larger than that of subject teachers, the only exception being adjustment of the assessment dates. In cases where teachers were not sure about the need for the extension of the set period for allowed assessment accommodations but nonetheless practiced accommodations after the expiration of the determined period, the question arises as to whether they answered with regard to the didactic principle of the individualisation that should be considered with each individual pupil. This certainly must not be true when lowering demands for pupils without Slovenian citizenship with regard to achieving knowledge standards, which proved to be the case with some teachers. The results indicate that some pupils without Slovenian citizenship obviously do not receive proper feedback on their knowledge, strengths and weaknesses, nor on how to improve in order to succeed in the educational process in the future. We regard this as unjust towards these pupils, who are equally entitled to achieve internationally comparable knowledge standards, but with regard to whom the achievement of these standards is not always demanded. The results of the secondary analysis of data from the PISA study show significant differences between native pupils' and immigrant pupils' reading achievement in Slovenia, as in the majority of other participating countries (Šori et al., 2011). The authors claim that the reasons for these differences lie in immigrant pupils' lower level of cultural capital, poor language proficiency, lower level of enjoyment in reading, pupils' use of less efficient summarising strategies, and the insufficient effort of countries to overcome these obstacles (ibid). However, the results of our research suggest another factor contributing to differences in the achievement of both groups of

pupils: teachers' lower demands for pupils without Slovenian citizenship with regard to knowledge standards. This is equally unjust to pupils with Slovenian citizenship, who have to show a higher level of knowledge in order to receive the same grade as their foreign classmates. Nevertheless, almost all the teachers, regardless of the grade they taught or their level of education, perceived the accommodated assessment and grading process as just, which is obviously in contradiction with the legislation as well as with the principle of justice. Qualitative research would thus enable us to develop an in-depth understanding of teachers' assessment practices with pupils without Slovenian citizenship.

Why are there differences between generalist teachers and subject teachers in practicing assessment accommodations after the expiration of the determined period? Possible reasons may lie in the fact that, in some subjects, pupils are grouped according to their ability in the higher grades of Slovenian primary school, and the fact that subjects in higher grades are more differentiated and are not as focused on developing basic skills and abilities. Perhaps subject teachers also perceive older pupils as having attended a Slovenian school for a longer period than they actually have, whereas generalist teachers have a better insight into the knowledge and basic skills of the individual foreign pupil, as well as of the Slovenian pupil, due to the longer period spent with the pupils. Considering the overall results, we conclude that it is important to treat pupils according to the principle of fair equality of opportunity, and to help them overcome their initial weaknesses by providing foreign pupils with preparational courses on Slovenian language, Slovenian culture and to acquaint them with the educational system, by adjusting teaching methods as well as practicing different assessment accommodations for them. However, considering the teachers' answers regarding practicing assessment accommodations even after the determined period, it may be reasonable to 1) analyse the type and quantity of educational assistance pupils without Slovenian citizenship receive as well as the possibilities that are at their teachers' disposal to help them, thus investing more effort in developing mechanisms aimed at improving the achievements of pupils without Slovenian citizenship, or 2) consider the extension of the legally defined period of allowed adjustments in the assessment process. In any case, educating teachers about ways of improving the knowledge of pupils without Slovenian citizenship, and about the importance of investing more effort in helping the pupils to achieve this goal, is crucial. Obviously, many teachers do practise various assessment accommodations even after the determined period, while others do not. This raises questions about the justice of such inconsistency in the treatment of pupils without Slovenian citizenship. We are convinced that accommodation of assessment criteria, in the sense of lowering demands

regarding the level of knowledge after the expiration of the normatively determined period (and outside the context of grouping pupils according to their abilities), results in the unjust treatment of all of the pupils, and more attention should therefore be devoted to this problem.

Finally, focusing on the exchange of information between generalist teachers and subject teachers regarding the level of knowledge, language skills and overall individual progress of a pupil without Slovenian citizenship is of great importance, and more attention should be devoted to this issue.

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Biographical note

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The Role of Cultural Capital in Higher Education Access and Institutional Choice

Iva Košutić[1]

This paper aims to explore social inequalities in school achievement and educational decision-making of the final-year students of secondary schools in the City of Zagreb and Zagreb County, Croatia (N = 534). The theoretical framework of the paper was Bourdieu's theory of cultural and social reproduction (1977a). The main objectives were an analysis of the association between the students' cultural capital and their school achievement and analyses of the predictive power of the cultural capital theory in the context of educational decisions in the transition to tertiary education. In the analysis of school achievement, sequential multiple regression analysis was used, while in the analyses of educational decisions logistic regression analyses were performed (binary and multinomial logistic regression). The results indicated that cultural capital had statistically significant correlation with school performance. Among the cultural capital indicators, statistically significant predictors of the probability of the intention to enrol into vocational higher education were the material dimension of cultural capital and naturalness of higher education aspirations of students. For the prediction of the probability of intention to enrol in university, significant predictors were embodied cultural capital, the naturalness of higher education aspirations of students, and father's educational level. The study results on a selected sample of graduates tend to support Bourdieu's theory of cultural reproduction through education.

Keywords: cultural capital; educational decisions; educational inequality; school achievement

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Vloga kulturnega kapitala pri dostopu do visokošolske izobrazbe in institucionalne izbire

Iva Košutić

Namen prispevka je raziskati socialne neenakosti v šolskih dosežkih in pri sprejemu izobraževalnih odločitev dijakov zadnjega letnika srednje šole v mestu Zagreb in občini Zagreb (N = 534). Teoretski okvir prispevka predstavlja Bourdieuejeva teorija kulturne in socialne reprodukcije (1977a). Glavna cilja sta bila analiza povezanosti med kulturnim kapitalom dijakov in njihovim šolskim uspehom ter analiza napovedne moči teorije kulturnega kapitala v kontekstu izobraževalnih odločitev v prehodu na terciarno raven izobraževanja. Pri analizi šolskih dosežkov je bila uporabljena analiza sekvenčne multiple regresije, medtem ko je bila pri analizi izobraževalnih odločitev uporabljena logistična regresija (binarna in multinominalna logistična regresija). Rezultati so pokazali, da je kulturni kapital statistično pomembno povezan s šolsko uspešnostjo. Med indikatorji kulturnega kapitala so kot statistično pomembni napovedniki verjetnosti namere za vpis v poklicno srednješolsko izobraževanje predstavljeni opredmetena dimenzija kulturnega kapitala in aspiracije dijakov. Pri napovedovanju verjetnosti namere za vpis na univerzo so bili pomembni napovedniki utelešen kulturni kapital, srednješolske aspiracije dijakov in izobrazbena raven očeta. Rezultati študije na izbranem vzorcu diplomantov podpirajo Bourdieujevo teorijo kulturne reprodukcije v polju izobraževanja.

Ključne besede: kulturni kapital, izobraževalne odločitve, izobraževalna neenakost, šolski dosežki

Introduction

Educational inequalities have long been the interest of sociologists of education as numerous studies continuously emphasise the association between students' social background and their educational performance. The period after World War II was marked by the need to 'change the elitist nature of universities' (Guri-Rosenblit, Sebkova, & Teichler, 2007, p. 1) by widening the access to students from all social strata, with expectations that wider access would eventually lead to greater opportunity for social mobility. This need stemmed from the fact that industry and job demands had changed, requiring more educated individuals on suitable positions, but also from the growing conscience that education is a human right: 'Technical and professional education shall be made generally available, and higher education shall be equally accessible to all on the basis of merit' (Universal Declaration of Human Rights, 1948). In line with international trends, data on the massification of higher education in Croatia from 1951 to 2014 show that the number of students had grown more than five-fold, which testifies to its 'exponential growth' (Baranović, 2015, p. 23). However, the widening of higher education and its massification and universalisation (Trow, 1974) decades ago did not substantially weaken the strength of association between family's social origin and educational pathways of the children (Karabel & Halsey, 1977; Van de Werfhorst, Sullivan & Cheung, 2003). Research shows that, despite various educational reforms, children from upper classes generally perform better in school and more frequently choose tertiary education than children from less privileged backgrounds do (Boalt 1947, Harnqvist 1958, Jencks & Riesman 1968, in Erikson, 2007; Erikson et al., 2005). An OECD report (2010) highlights the importance of parents' socio-economic status (SES) for educational performance of the children in all OECD countries and emphasises the fact that inequalities in secondary education translate into inequalities in tertiary education, and later in inequalities in occupation and income. Eurostat's *Intergenerational transmission of disadvantage statistics* (2013) emphasises the association of parents' and children's levels of education.

The Eurostudent report for Croatia (2011) showed similar trends: students whose parents have completed less than four years of secondary education are underrepresented in tertiary education. A comparative international Eurostudent report (2011) thus labels the Croatian higher education system as socially exclusive, characterised by 'high level of underrepresentation of students from low education backgrounds and a high level of overrepresentation of students from high education backgrounds' (Eurostudent, 2011, p. 2). The importance of the social dimension in higher education on a European level

is emphasised in various documents (see *Europe 2020*, 2010; Leuven Communiqué, 2009; London Communiqué, 2007; Prague Communiqué, 2001) and recently in Croatia in the national *Strategy of Science, Education and Technology* (2014) whose aim is, among others, to accomplish 'general accessibility of higher education in order to ensure socially equitable system' (2014, p. 93).

Despite international trends in research on educational inequalities, there has been a lack of empirical sociological research of such phenomena in Croatia, with even fewer studies exploring the potential mechanisms behind educational inequalities. Babarović, Burušić and Šakić (2009), Burušić, Babarović and Marković (2010), Jokić and Ristić Dedić (2010) examine, among other factors, the relationship between family background and school performance of elementary school pupils, Gregurović and Kuti (2010), Matković (2010), Puzić, Gregurović and Košutić (2016) on secondary school students, and Puzić, Doolan and Dolenec (2006) and Doolan (2009) amongst university students. In order to investigate the educational inequalities in a Croatian setting, this paper[2] follows a critical perspective and examines the inequalities in school performance and access to higher education for students of different social origin using Bourdieu's cultural reproduction theory (1977a). This study had also contributed to the collection of primary data on the topic, which has been approached, thus far, in Croatia mainly through secondary data.

Theory of Cultural and Social Reproduction

Bourdieu's theory of social reproduction (1977a) focuses on the cultural aspects of social inequality, investigating which social mechanisms create and perpetuate social reproduction and enable the maintenance of a classed society. According to Bourdieu (1973, 1977a, 1986, 1990), the most important mechanism of social reproduction is the reproduction and legitimisation of social inequalities via the reproduction of the culture of the dominant classes. Bourdieu acknowledges the importance of the obvious mechanisms of social reproduction, maintained through the transfer of economic inequality, but he stressed the importance of a less obvious and, therefore, more significant mechanism of maintaining social inequalities: the reproduction of the culture of the dominant classes. For Bourdieu (1977a), the educational system is the key factor in legitimising existing social structures and class relations, because it is based on standards and knowledge of the upper classes. The educational system, which

2 The data for this paper were collected during the research project 'Social identities, higher education access and course choice' funded by the Croatian Science Foundation (project No. 09.01/404).

is characterised by 'apparently neutral attitude' (Bourdieu, 1977a), reflects the existing power relations in wider society and favours children familiar with the dominant culture: 'This consists mainly of linguistic and cultural competence and that relationship of familiarity with culture which can only be produced by family upbringing when it transmits the dominant culture.' (Bourdieu 1977a, p. 494). This means that the school system is not compensating for the lack of such competencies to the children from less privileged family backgrounds, who experience schools as unnatural and intimidating environments. As a consequence, pupils of lower social origin adapt with more difficulty to the school culture, have generally lower school performance and lower educational and professional aspirations. The educational system is, therefore, an important factor in maintaining social inequalities, as students from educationally, financially, and socially privileged families achieve higher educational and professional success and thereby reproduce patterns of social stratification and retain their inherited positions of power. Goldthorpe notes that social reproduction is thus 'doubly guaranteed' (2007, p. 11): by transmission of family's capital to children and by passive role of an educational system that does not enable social transformation.

Different family class positions form different systems of thought and reasoning, a specific way of thinking, which Bourdieu refers to as 'habitus'. For Bourdieu, habitus is 'a system of lasting, transposable dispositions which, integrating past experiences, functions at every moment as a matrix of perceptions, appreciations, and actions' (Bourdieu 1977b, p. 82–83). Habitus is a way of understanding the world, an individual's 'mental structure' (Bourdieu, 1989, p. 18), which contributes to social reproduction. The importance of the habitus primarily attained in the family is in the fact that it forms a basis for acceptance and comprehension of the messages in the classroom. Thus, the family habitus affects children's predispositions towards school and the affinity to invest time, effort, and money to preserve the family's capital and social status.

Bourdieu differentiates several types of capital, all valuable in the educational system and vital for understanding social inequalities in general: economic, social and cultural capital (Bourdieu, 1997). Cultural capital is the most useful form of capital in the educational system (Dumais, 2006). It is a form of symbolic power that can be, via education, transformed into economic capital (Bourdieu, 1997; Swartz, 1997). According to Bourdieu (1997), cultural capital exists in three forms: as embodied (incorporated in person: linguistic competences, cultural affinities, taste), objectified (material form of cultural capital: possession of cultural goods such as books, paintings, works of art, etc.) and institutionalised (educational qualifications). For upper-class children, the

transmission of cultural capital starts immediately, in family, and is naturally followed in schools (Bourdieu, 1986). Teachers recognise and reward the possession of cultural capital in subtle ways; they communicate better with children who possess more cultural capital and even 'perceive them as more intelligent or gifted than students who lack cultural capital' (DiMaggio 1982, p. 190). In contrast, children from less privileged family backgrounds lack cultural capital at home and are thus in an inferior position in the educational system.

For Bourdieu (1997), cultural capital can be converted into economic capital only through the educational system, which confirms the possession of cultural capital in the form of educational qualifications. These qualifications then potentially translate into economic capital. Convertibility is, therefore, the basis of strategies to ensure the reproduction of capital over time (Bourdieu, 1997, p. 54). Due to its significance for the educational system, this paper focuses on Bourdieu's concept of cultural capital as a key factor in the transmission of social inequalities.

Cultural Capital in Educational Research

Bourdieu did not precisely define nor limit the cultural capital concept, although he did make some references to specific cultural practices (such as visits to theatres, concerts, and museums) and the possession of cultural goods (Bourdieu, 1984). For that fact, in empirical studies of educational inequality, cultural capital is operationalised in various ways. DiMaggio's (1982) work on the association between American high school students' cultural capital and their academic performance is often cited in literature as one of the most influential studies on this topic (Kingston, 2001; Lareau & Weininger, 2003). Starting from Weber's (1968) notion of 'status culture', DiMaggio operationalised cultural capital as a participation in the elite status culture, in 'art, classical music and literature' (DiMaggio, 1982, p. 191). DiMaggio's analyses indicated a positive association between students' possession of cultural capital and school grades, with especially strong impact on grades in nontechnical subjects. However, the impact of cultural capital was found to be most significant for the males from lower social origin, which was interpreted as a proof of the cultural mobility model (stating that cultural capital affects educational performance regardless of social origin; its possession is not tied only to dominant classes). That finding was supported by Kalmijn and Kraaykamp's (1996) study that showed that cultural capital can compensate for disadvantages related to social origin. Although DiMaggio's operationalisation of cultural capital as participation in high-class activities is among most frequently used in quantitative research (Barone, 2006), some

researchers extended the concept of cultural capital on students' and family's reading practices. On a representative sample of 15-year olds in the Netherlands, De Graaf (1986) found a statistically significant effect of parents' reading practices on their children's educational performance, regardless of the socioeconomic status of the family. The importance of reading practices for school attainment was supported by De Graaf's (1988) study on a German sample of high school students and by a study of De Graaf et al. (2000) on a Netherlands sample. Both studies stress the importance of family's reading climate for the development of linguistic and cognitive competencies that affect school success and that can, to a certain extent, compensate for a low socioeconomic status of the family.

The mentioned indicators referring to the cultural practices of students and their families facilitate the attainment of embodied form of cultural capital, while some studies also include the operationalisations of cultural capital indicators of its material dimension. This refers to possession of cultural goods and objects of art (books, dictionaries, musical instruments, etc.) whose disposition at home could be helpful to children in educational process (Barone, 2006; Jæger, 2009, 2011; Sullivan, 2000; Teachman, 1987). These studies indicated that the possession of these potential educational resources is associated with children's school success.

A number of studies of cultural capital in education have addressed the interactive aspects of the family environment (Barone 2006; Downey, 1995; Jaeger, 2009, 2011; Tramonte & Willms, 2010), and school environment, that is the interaction of students and parents with teachers and other relevant stakeholders of the educational process (Lareau & Horvat, 1999). In the first case, the specific family patterns of interaction and communication through which parents transmit their cultural capital (as part of a family habitus) to children were examined; in the second case, studies examined the ways in which students and their parents use cultural capital in order to obtain preferential treatment and accomplish school success (Jæger, 2009).

The previously discussed studies mainly confirm the importance of the effect of the students' and family's cultural capital on the educational achievement of children, even in different social and educational contexts. Following similar research, this article analyses the elements of embodied and objectified cultural capital of parents and students and some aspects of their interactions.

Research Objectives and Hypotheses

The main objectives of this paper were the analysis of the association between the students' cultural capital and their school achievement, as well as

the analysis of the predictive power of the cultural capital theory in the context of educational decisions in the transition to tertiary education. In line with the set objectives, the following hypotheses were formulated:

Hypothesis 1. The possession of cultural capital is positively related to students' school achievement. The basis of Bourdieu's (1977) theory is the notion that the educational system rewards the possession of cultural capital and converts it into educational success. Although numerous studies (DiMaggio, 1982; De Graaf, 1986, 1988; De Graaf et al., 2000; Flere et al. 2010; Kalmijn and Kraaykamp, 1996; Kingston, 2001; Sullivan, 2000) indicate that the possession of cultural capital is associated with educational achievement, there is a lack of detailed research in a Croatian setting. Thus, the hypothesis was formulated in accordance with the previous international findings.

Hypothesis 2. The students with greater possessions of cultural capital are more likely intend to continue to tertiary education at university than students with lower levels of cultural capital do.

Hypothesis 3. The students with greater possessions of cultural capital are less likely intend to continue to tertiary education at polytechnic schools than students with lower levels of cultural capital do. These two hypotheses are based on Bourdieu's (1977) assertion that the continuation of schooling is the natural and logical choice for students in greater possessions of cultural capital, who often come from privileged social backgrounds. The decision to continue education at university (prestigious institution) provides continuity in maintaining the family's high social status (cultural reproduction through education leads to social reproduction).

Methods

Sample

The study was conducted on N = 534 students in their final year of high school (age of the students was from sixteen to eighteen years). The sample included 5% of the population of students in the finale school year in the City of Zagreb and Zagreb County,[3] which included 18 schools in Zagreb (427 stu-

3 Zagreb County is the surrounding area of the capital city Zagreb. It has a population of 317,642 people situated in nine cities, 25 municipalities and 697 settlements. The region was chosen for the sampling to achieve greater variability of the SES and cultural capital; Zagreb County has fewer adults with finished higher education than the City of Zagreb does (12.89% vs. 28.98%), relies more on agriculture and has a 22% lower average monthly net income per capita than the City of Zagreb does (Croatian Bureau of Statistics - Census, 2011).

dents) and five schools (107) in Zagreb County, representative with regard to gender and school type (three- or four-year vocational school, gymnasium (academic-oriented secondary school)). The questionnaire survey was conducted in schools, during one school hour. Only one class of the students (randomly selected by the school personnel) in each school participated in the survey. The survey was anonymous and included the informed consent of the students.

Measures

Dependent variables

School achievement – This variable included the students' general grade-point averages at the end of their previous school year (open answer).

Aspirations for higher education – Students' intention to proceed or not to proceed to tertiary education after secondary school. The variable had two categories – 'I intend to proceed to tertiary education' (1) and 'I do not intend to proceed to tertiary education' (2).

Likelihood of continuing education at university – students reported the likelihood of their attempting to continue education at the university/academy level on a scale from 1 ('definitely will not') to 5 ('definitely will'). After inspection of the distribution of answers, the variable was recoded into three categories: 'Definitely not/probably not/I am not sure' (1), 'Probably will' (2) and 'Definitely will' (3).

Likelihood of continuing education at polytechnic school or professional higher education institution – students reported on a scale from 1 ('definitely will not') to 5 ('definitely will') try to continue education at the non-university tertiary level. After the inspection of the distribution of answers, the variable was recoded into two categories: 'Definitely not/probably not/I am not sure' (1) and 'Probably will/definitely will' (2).

Independent variables

Secondary school type – The students were asked what type of secondary school they attend (three-year vocational school, four-year vocational school or gymnasium). In the regression models, the variable was recoded into a dummy variable for each school type.

Parents' cultural capital – The variable was created as a composite index containing six items representing the embodied forms of cultural capital: parents' frequency of museums/art galleries visits, frequency of theatre visits, frequency of opera/ballet/classical concerts visits, frequency of reading prose, frequency of reading non-fiction books, and frequency of participation in

educational programmes/courses. Students reported on a scale from 1 ('never') to 5 ('very often'). Cronbach's α for the index was 0.81.

Parental education – This variable was based on the students' answers on their parents' highest educational level (both mothers' and fathers'). The variables had five categories: (un)finished elementary school (1), finished three-year vocational school (2), finished four-year high school (vocational or gymnasium) (3), finished non-university tertiary education (4) and finished university/doctoral degree (5).

Transfer of cultural capital - The variable was created as a composite index containing three items measuring the parents' support to students. Students reported on a scale from 1 ('strongly disagree') to 5 ('strongly agree') regarding the following statements: 'My parents are interested in what I do in school', 'My parents help me with school tasks when needed' and 'My parents encourage me to continue education'. Cronbach's α for the index was 0.64.

Students' material cultural capital – This variable was created as a composite index containing two variables: *The number of books in the household* (students' estimates on the number of books in their household, ranging from 1 ('0-10 books'), to 6 ('more than 500 books') and *Index of educational resources* (sum of students' positive answers on the possession of computer, own room, study table, books, internet connection, dictionaries, classic books, books in foreign languages, works of art, and music CDs).

Students' embodied cultural capital – This variable was created as a composite index containing three variables: *Students' cultural practices* (a composite variable of five items- frequency of: museums/art galleries, theatre, opera/ballet/classical concerts, cinema and pop/rock concerts visits. Students reported on a scale from 1 ('never') to 4 ('more than four times a year'), *Participation in extracurricular activities* (a composite variable consisting of four items: drama group, ballet/dance, choir and music school attendance) and *Students' reading practices* (a composite variable consisting of three items: frequency of students' reading non-fiction books, popular-science/culture magazines and poetry/prose). Students reported on a scale from 1 ('never/almost never') to 5 ('several times a week/every day').

Naturalness of higher education[4] – According to Bourdieu (1977, 1997), for the students of privileged social backgrounds, the completion of higher education is an implied, natural sequence of events. To test the student's understanding of the naturalness of study, a categorical variable was constructed. The students chose one out of three possible choices: 'It implies to me that I will

4 The variable name was shortened from the phrase 'naturalness of higher education aspirations of students'.

enrol into higher education', 'It implies to me that I will not enrol into higher education', and 'I cannot tell if it implies or not to me that I will enrol into higher education' (student does not *infer* either outcome). This variable was recoded into dummy variables in the regression models.

Socio-economic status of the family (SES) – This variable was created as a composite index containing four variables: *owning a computers/cars/real estate*, *financial position of the family*, *social position of the family*, and *ISEI*. *Owning a computers/cars/real estate* referred to possessions of these goods in the family; *financial position of the family* referred to students' subjective assessment of the family's financial situation; *social position of the family* referred to students' subjective assessment of the family's social status (on the scale from 1 ('lowest position') to 10 ('highest position')). The *ISEI* (*International Socio-Economic Index of occupational status)* was created on the basis of students' answers about the employment of their parents and descriptions of the job they do. The open answers about parents' jobs and employment were first coded into the *International Standard Classification of Occupations* (*ISCO*) codes (ILO 1990), then transformed into the ISEI using IBM SPSS Statistics syntax from Ganzeboom (2013). The ISEI included highest ISEI of the parent (mother's or father's).

Statistical procedures

In the first step, bivariate (Pearson) correlations between dependent and independent variables were analysed. In the analysis of school achievement, sequential multiple regression analysis was used, while in the analyses of educational decisions logistic regression analyses were performed (binary and multinomial logistic regression).

Results

Table 1 displays correlations between school performance and explanatory variables (except categorical variables) used in the analysis. The strongest association was between the variables of parents' cultural capital and family SES. Other significantly associated variables were the parents' and students' cultural capital, as well as the parents' cultural capital and the transfer of cultural capital. Students' embodied cultural capital was significantly associated with the family SES and school achievement, while school achievement was significantly associated with the family SES, but not with the parents' cultural capital and the transmission of cultural capital.

Table 1. *Correlations between school performance and explanatory variables*

	Parents' cultural capital	Students' embodied cultural capital	Family SES	Transfer of cultural capital	School achievement
Parents' cultural capital	1	0.42**	0.57**	0.22**	0.80
Students' embodied cultural capital		1	0.24**	0.73	0.15**
Family SES			1	0.11**	0.12**
Transfer of cultural capital				1	0.61
School achievement					1

** $p < 0.01$

To provide a more detailed insight of the impact of the explanatory variables on the selected educational outcomes, multivariate analyses predicting school performance and educational decisions were conducted. Table 2 presents five regression models with school achievement as an independent variable.

Table 2. *Multiple regression models for predicting school achievement*

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Beta	*p*	*Beta*	*p*	*Beta*	*p*	*Beta*	*p*	*Beta*	*p*
Gender (0=M, 1=F)	0.19	0.00	0.20	0.00	0.20	0.00	0.20	0.00	0.18	0.00
3-year vocational school*	-0.32	0.00	-0.31	0.00	-0.28	0.00	-0.28	0.00	-0.17	0.00
4-year vocational school	-0.20	0.00	-0.20	0.00	-0.17	0.00	-0.18	0.00	-0.15	0.00
Mother's education			-0.03	0.54	-0.06	0.23	-0.05	0.37	-0.06	0.24
Father's education			0.03	0.50	-0.00	0.94	0.00	0.97	0.01	0.90
Family SES					0.02	0.73	0.03	0.60	0.04	0.47
Students' material cultural capital					0.15	0.00	0.17	0.00	0.14	0.01
Parents' cultural capital							-0.08	0.14	-0.08	0.16
Transfer of cultural capital							0.03	0.49	0.02	0.57
Implies enrolling into HE**									0.19	0.00
Implies not enrolling into HE									-0.03	0.48
Students' embodied cultural capital									-0.01	0.89

	Model 1		Model 2		Model 3		Model 4		Model 5	
	Beta	*p*	*Beta*	*p*	*Beta*	*p*	*Beta*	*p*	*Beta*	*p*
	R^2= 0.13 F= 24.769 p= 0.00		R^2= 0.13 F= 14.940 p= 0.00		R^2= 0.15 F= 12.392 p= 0.00		R^2= 0.15 F= 9.913 p= 0.00		R^2= 0.18 F= 9.27 p= 0.00	

* Referent category: 'Gymnasium'
** HE= higher education. Referent category: 'Does not imply either outcome'

Analyses indicated that cultural capital and SES variables explain between 13% and 18% of the variance of the school achievement. In the first model, female gender was positively associated with achievement, as well as attending gymnasium in relation to vocational schools. In the second model, the variables of parents' education were not significantly associated with school achievement. In the third model, family SES and students' material cultural capital variables were added. The latter was a significant predictor (family SES was not). The introduction of the material dimension somewhat reduced the coefficients of the school type, although they remained statistically significant (Beta coefficient for the three-year school has decreased by about 9%, and for a four-year school by 15%). The third model explained an additional 2% of the variance criteria (from 13% to 15% in total). In the fourth model, variables of relational dimensions of cultural capital were added, i.e. parents' cultural practices and the transmission of cultural capital. These predictors were not statistically significant, and the contribution of previously significant predictors remained the same. In the last model, the variable 'implies the enrolment into HE' was statistically significant predictor for school achievement, while the variable of embodied cultural capital was not. The fifth model explained an additional 3% of the variance in comparison to the fourth model, and all variables explained 18% of the variance of the school achievement of students.

Table 3 presents the results of a binary logistic analysis showing the probability of students' decision to enrol into polytechnic schools.

Table 3. *Logit model for predicting probability of enrolment into polytechnic school (referent category: 'probably will/definitely will' enrol into polytechnic school)*

(n= 493)	B	S.E.	OR	95% C.I. OR	
				Min.	Max.
Gender (0=M, 1=F)	-0.31	0.24	0.73	0.46	1.19
School type					
Gymnasium (referent)	0		1		
3-year vocational school	0.72	0.43	2.06	0.88	4.83
4-year vocational school	1.36	0.30	3.90**	2.18	6.97
Father's education	-0.03	0.12	0.97	0.77	1.22
Family SES	0.00	0.01	1.00	0.99	1.01
Students' material cultural capital	0.12	0.05	1.13*	1.02	1.25
Parents' cultural capital	-0.04	0.03	0.96	0.90	1.03
Naturalness of higher education					
Implies the enrolment into HE (referent)	0		1		
Implies not to enrol into HE	-1.94	0.79	0.14*	0.03	0.68
Does not imply neither outcome	-1.04	0.32	0.35**	0.19	0.66
Students' embodied cultural capital	0.04	0.03	1.04	0.99	1.09
School achievement	-0.60	0.21	0.55*	0.37	0.83
Constant	-0.76	1.06	0.47		

*p< 0.05; **p<0.01

Polytechnic schools in Croatia are traditionally associated with lower prestige than university study. Therefore, whether students from various cultural and socio-economic backgrounds differ with regard to the distinction between the two types of institutions was analysed.[5] In this model, statistically significant predictors, controlling for the other variables, were the school type, students' material cultural capital, naturalness of higher education and school achievement. Students who attend four-year vocational schools were almost four times more likely to express the intention of enrolling into polytechnics then students who attend gymnasiums. The material dimension of cultural capital was also positively correlated with the intention of continuing their education at the polytechnics. School achievement was significantly and negatively associated with the intention of enrolling into polytechnics: a reduction of one unit value of school achievement increased a chance for intention of continuing education at a polytechnic by 45%.

5 Due to the insignificant correlation with the dependent variable, the variable transmission of cultural capital was excluded from the analysis. Furthermore, mother's education was not included in logistic regression analyses because father's education had stronger correlations with the dependent variables.

Table 4 presents the results of the multinomial logistic regression for the probability of students' intention of enrolment into university, using the same independent variables as for prediction of intention of enrolment into polytechnics.

Table 4. *Logit model for predicting probability of enrolment into university (referent category: 'definitely will' continue education at the university)*

	Definitely not/probably not/ I am not sure (n=135)	***Probably will (n=111)***
	AOR (95% CI)	*AOR* (95% CI)
Gender = M	0.80 (0.42-1.53)	1.26 (0.73-2.20)
3-year vocational school	36.25 (10.60-124.00)	4.01 (1.51-10.61)**
4-year vocational school	5.08 (1.81-14.26)	1.73 (0.95-3.16)*
Gymnasium	1	1
Father's education	0.74 (0.53-1.02)	0.77 (0.59-1.00)*
Family SES	1.01 (0.99-1.02)	1.01 (1.00-1.03)
Students' material cultural capital	0.94 (0.83-1.08)	0.95 (0.84-1.06)
Parents' cultural capital	0.92 (0.84-1.01)	0.94 (0.87-1.02)
Implies the enrolment into HE	0.09 (0.04-0.19)	0.15 (0.07-0.31)**
Implies not to enrol into HE	0.70 (0.13-3.87)	0.00 (0.00-0.00)
Does not imply neither outcome for enrolment into HE	1	1
Students' embodied cultural capital	0.89 (0.83-0.96)**	0.92 (0.86-0.98)**
School achievement	0.27 (0.16-0.48)**	0.37 (0.23-0.59)**

*p< 0.05; **p<0.01
AOR = odds ratio corrected for the contribution of other independent variables in the model

Statistically significant predictors, with control of other variables in the model, were students' embodied cultural capital, school achievement, type of high school, father's education, and naturalness of higher education. With an increase of one unit of students' embodied cultural capital, the students were 11% less likely to respond 'definitely not/probably not/not sure' in relation to the answer 'definitely will,' for the intention of continuing to university. School achievement was also negatively associated with selecting the answer 'definitely not/probably not/not sure' in relation to the answer 'definitely will'. A reduction of the unit value of the variable school achievement increased the chance to answer 'definitely not/probably not/not sure' in relation to the answer 'definitely will' by 73%. Students of vocational schools were more likely than gymnasium students to answer that they would not try to continue their education at university (or are not sure of it), controlling for the other predictors in the model.

For students attending three-year vocational schools, a chance for that answer is 36 times higher than for the gymnasium students, and for students of four-year vocational school about five times higher. Students who find it natural to continue to higher education have a greater probability of answering that they will probably continue to university than students who do not infer any outcome. Furthermore, a reduction of unit value for the variable father's education by 23% increased the chance of the answer 'probably will' in relation to the answer 'definitely want' (to continue education at university), controlling for other variables.

Discussion

Multiple regression analysis showed that the material dimension of cultural capital and the naturalness of higher education, as an expression of a specific family habitus, were associated with school achievement. Therefore, it can be concluded that *Hypothesis 1* was confirmed. It should be noted that the hypothesis was confirmed only partially, because not all indicators of cultural capital were significant predictors. A conceptually more important dimension, students' embodied cultural capital, was not a significant predictor of overall school achievement, nor was parents' education. Therefore, the confirmation of the hypothesis should be taken with caution, because the material dimension of cultural capital can indicate the level of economic capital. Based on this finding, it seems that the family's material circumstances affected the students' school achievement more than the relational dimension of cultural capital did. This may be due to the fact that material resources can quickly be converted into knowledge (investing in private tutorship/course to enhance knowledge gained in schools), whereas the transmission of cultural capital at home, besides being time-consuming, depends on levels of cultural capital of the parents and their will and ability to help children with school tasks. Moreover, it may be assumed that the students with higher school achievement need their parents' help in school tasks less. However, one of the study limitations is the relatively modest number of indicators of the transfer of cultural capital, so this finding should be taken with caution. Numerous studies (DiMaggio, 1982; De Graaf, 1986, 1988; De Graaf et al., 2000; Flere et al. 2010; Kalmijn and Kraaykamp, 1996; Kingston, 2001; Sullivan, 2000) confirm that the possession of cultural capital is associated with higher educational success; the findings obtained are only partially in accordance with the relevant findings of similar studies.

Logistic regression analysis for the decision to continue education at polytechnic school showed that the higher possession of cultural resources

(material cultural capital) was positively correlated with the intention of enrolling into polytechnics and negatively with school achievement. Thus, *Hypothesis 3* is partially confirmed; the material cultural capital being significant predictor, but not the embodied forms of cultural capital. Polytechnics in Croatia are mainly private institutions; hence the finding that the material dimension of cultural capital affects the likelihood of intention of enrolling into polytechnics was expected. In accordance with these findings, it would be logical to expect that the family's SES was a significant predictor of enrolment into polytechnics; however, it was not significant in the analysis. One possible interpretation is that the polytechnic education attracts children who do not have high school achievement, but their parents have certain material conditions or possess cultural capital that encourages them to acquire at least a polytechnic higher education qualifications, while families with high SES but not the material dimension of cultural capital, do not insist on obtaining higher education qualifications.

The analysis of the decision to continue high school education at university indicated that the significant and positive predictors of the likelihood of expressing the intention of enrolling in university were students' embodied cultural capital, father's education, school type (gymnasium), school achievement, and the naturalness of higher education for students. The significance of important predictors of cultural capital indicated that *Hypothesis 2* was confirmed. These results may indicate that the high school differentiation of 'cultural capital light' and 'cultural capital heavy' institutions *(*Jæger, 2009, p. 1951) can be applied to the university and polytechnic education (for the decision on enrolling into polytechnic institutions, the parents' cultural capital was not significant, nor was students' embodied cultural capital), as a new form of maintaining social distance between different social classes. Since the educational expansion of tertiary education has enabled the influx of a large number of students from all social strata (although not in equal proportions), the differentiation of classes has changed in the qualitative distinction between types of higher education institutions and fields of study (Bourdieu, 1984). Van de Werfhorst, Sullivan and Cheung (2003) have shown that students from upper-class families more often chose prestigious higher education fields than the children of unskilled manual workers did.

Overall, it can be considered that the results of this study on a selected sample of graduates tend to support the evidence of previous findings based on Bourdieu's theory of cultural reproduction. Students from privileged social backgrounds tend to have better educational achievement than their peers from less privileged backgrounds do, and more frequently have aspirations to

continue their education at the university. Although it would be necessary to analyse the entire educational and professional path of the students and their parents to confirm the maintenance of social inequality through education, it could be considered that these study results tend to support the reproduction thesis for the selected population of students.

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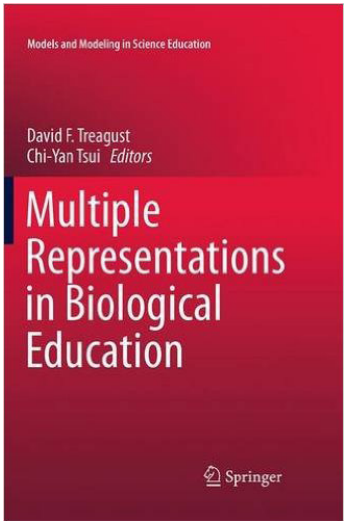
Biographical note

Iva Košutić, PhD, is a postdoctoral fellow at the Institute for Social Research – Zagreb, Centre for Educational Research and Development. She received her PhD in sociology in 2015 at the Faculty of Humanities and Social Sciences, University of Zagreb. Her fields of interest include sociology of education, with the emphasis on social dimension of higher education. She has research experience in the field of education; her research projects so far included various topics – the quality of compulsory education, the social dimension of secondary education, financing of the higher education, equity in higher education, higher education/study choice.

Treagust, David F. and Tsui, Chi-Yan (Ed.) (2013). Multiple Representations in Biological Education, Models and Modeling in Science Education (Volume 7). Dordrecht, Heidelberg, New York, London: Springer. 390 p. ISBN: 978-94-007-4191-1 (print version)

Reviewed by Gregor Torkar[1]



Why should we read this book? I can think of at least two major reasons why the book entitled *Multiple Representations in Biological Education,* published by Springer in 2013 in the Models and Modeling in Science Education series, is essential reading for anyone involved in biology education.

The first has to do with the lifestyle of people, especially youth, in contemporary societies. The situation in economically undeveloped, developing, and developed societies around the world is far from equal; nevertheless, there is a common trend of peoples' growing displacement from the natural environment. Today, on average, children and adolescents spend less time outdoors, playing and discovering things, resulting in a wide range of problems that Richard Louv (2005) labelled 'nature deficit disorder'. The term is receiving increasing attention in the relevant literature. Direct contact with living things in natural environments provides information and experiences that learners use in school as a solid base to construct a deeper understanding of the world. Unfortunately, the current state of primary and secondary schooling remains unchanged, and learning outcomes are to the greatest extent still realised in the classroom. The content of the book provides a synthesis of international research on using visualisations, analogies and other means of external representations to improve higher-order learning. In particular, modern modes of representation, like virtual reality, might influence narrowing the gap described above. However, this cannot replace direct experiences in nature!

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Second, an equally or even more important reason for studying the content of the book is, in my opinion, the current position of biology as a natural science. In recent decades, biology has evolved from classical (descriptive) to modern (explanatory) science. Following the era of engineering (19th century), chemistry and physics (20th century), biology is starting to play a key role in tackling the global/complex problems of the 21st century. Biology education is following these changes. For example, the Biological Sciences Curriculum Study (2009) has identified six unifying principles in biology that can help organise the biological content of a course and the patterns and processes of natural phenomena in the living world: (1) evolution, (2) Interactions and interdependence, (3) genetic continuity and reproduction, (4) growth, development and differentiation, (5) energy, matter and organisation, (6) maintenance of a dynamic equilibrium. Similarly, in the book under review, The Biological Sciences Curriculum Study's approach to biology is named 'the domain knowledge of biology' and described as a body of extensive and complex knowledge about life and living organisms, which incorporates the integration of other disciplines, particularly chemistry, physics, and mathematics. Therefore, illustrating teaching and learning strategies to enhance students' ability to construct mental models and internal representations with the use of multiple external representations will assist them in understanding biology-related issues, such as societal problems about food, the environment, energy and health.

This book consists of 19 chapters arranged in three thematic parts. Part I is entitled Role of Multiple Representations in Learning Biology and consists of six chapters. Authors discuss the important roles multiple external representations have in biology education in order to make learning and teaching most effective. Part II is entitled Implications for Biology Teaching and Teacher Education and consists of seven chapters, which mainly provide examples of teaching biology with multiple external representations. Part III is entitled Assessment of Learning and Teaching with Multiple Representations and consists of six chapters. This part provides some methods on how to assess learning with multiple external representations.

First, let me point out the introductory chapter, written by editors David Franklin Treagust and Chi-Yan Tsui, which introduces the theoretical perspectives of this book. It is a 'must read' chapter for understanding the importance multiple external representations play in biological education. Especially valuable is the three-dimensional model or the cube model for learning biology with multiple external representations. The first dimension represents modes of representation like pictures, diagrams, graphs and equations, organised on the cube according to increasing abstraction. The second dimension represents four levels

of representation. What is unique for biology learning is complex, hierarchical organisation of life and nested knowledge domain, which gives, in their opinion, rational for using four learning levels of representation (macro, micro, submicro, and symbolic levels) instead of the three levels (macro, submicro and symbolic levels) proposed by Johnstone (1991) in chemistry education. The third, previously discussed, dimension represents the domain knowledge of biology.

The following 17 chapters in the book can be studied in no particular order. These chapters are a collection of empirical studies (e.g. Secondary Students' Understanding of Genetics Using BioLogica: Two Case Studies; Deconstructing and Decoding Complex Process Diagrams in University Biology) and theoretical expositions (e.g. Pictures in Biology Education; Possible Constraints of Visualisation in Biology: Challenges in Learning with Multiple Representations). The editors explained that '[…] these chapters differ in both the content areas and contexts within which learning and teaching take place in different languages in more than ten countries' (p. 350). In the final chapter of the book, the editors conclude by highlighting important aspects of presented research which can contribute to biology teacher education in terms of developing teachers' pedagogical content knowledge. Pedagogical content knowledge offers ways of engaging students in the content and ways how specific content can be successfully taught (Loughran et al., 2008).

Overall, the book makes very interesting reading, containing a great deal of high quality information. On the back cover, the most important aspects are well articulated: 'Addressing a major gap in the literature, the volume proposes a theoretical model for advancing biology educators' notions of how multiple external representations (MERs) such as analogies, metaphors and visualisations can best be harnessed for improving teaching and learning in biology at all pedagogical levels.' To conclude, I highly recommend this book to student teachers, teachers and researchers in biology education and related disciplines.

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