Teaching Higher-Order Thinking and Powerful Geographical Knowledge Through the Stage 5 Biomes and Food Security Unit

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Abstract

The article outlines ways that teachers could use the content in Biomes and Food Security unit in the Australian curriculum, and its state and territory versions, to encourage their students to engage with higher order thinking. It first briefly discusses how to describe and classify higher-order thinking and argues that concepts are central to this thinking. It also argues that powerful knowledge, an idea associated with Michael Young, develops the same ways of thinking. The article then discusses the higher order actions of explaining (in the sense of explaining causation), analysing, synthesising (or generalising) and evaluating, and how they can be applied to the content of the unit. The contribution of geography's major concepts (such as place and interconnection) to higher order thinking, and therefore to making the unit *geographical*, is also discussed. The article concludes with a description of a way of teaching the unit as an extended inquiry, organised as a series of questions. This strategy provides many opportunities to use higher order thinking, because to answer the questions students will have to explain, analyse, synthesise, generalise and evaluate, while the whole unit becomes an exercise in problem solving.

Introduction

> It is hard to imagine a teacher or school leader who is not aware of the importance of teaching higher-order thinking skills to prepare young men and women to live in the 21st Century. However, the extent to which higher-order thinking skills are taught and assessed continues to be an area of debate, with many teachers and employers expressing concern that young people 'cannot think'. (Collins, 2014).

This aim of this article is to show teachers ways of using the content of the Biomes and Food Security unit in the Australian Curriculum: Geography, and its state and territory versions, to help students develop these important higher-order thinking skills. The article starts with a discussion of what is meant by higher-order thinking, and identifies specific forms of this thinking that can be applied to the content of the unit.

Higher-order thinking

Lewis and Smith (1993), define higher order thinking as occurring when:

> a person takes new information and information stored in memory and interrelates and/or rearranges and extends this information to achieve a purpose or find possible answers in perplexing situations (Lewis & Smith 1993, p. 136).

In other words, higher order thinking happens when students go beyond recalling knowledge and can demonstrate their understanding in increasingly complex and creative ways to solve real-life problems, make reasoned judgements based on a variety of perspectives, synthesise key points and present informed predictions. Several taxonomies have been developed to describe and classify the cognitive processes involved in higher order thinking, and to arrange them in a hierarchy of increasing cognitive demand. In Table 1, three of these taxonomies are compared, using verbs to describe what students would do at each level. There are obvious differences between the taxonomies, especially in how they group items and where they place them in a hierarchy, but there is also considerable agreement on the thinking activities that are involved. From them, we have selected a few to illustrate how they can be developed through the Biomes and Food Security unit.

In addition, we want to highlight the use of geography's major concepts in higher order thinking, because conceptual application and analysis are essential to higher levels of geographical thinking. As Young (2010, p. 25) writes, “intellectual development is a concept-based not a content-based or skill-based process”. For example, concepts enable students to think about the abstract attributes of the phenomena they study. Young (2010) describes this as making the world ‘an object of thought’ rather than ‘a place of experience’, and he illustrates this with the example of the city. As an object of thought, students learn that cities have functions, such as retailing and manufacturing, not just shops and factories, and that understanding these functions and patterns enables them to compare cities. Another role of concepts is to form generalisations, which have been described as “a synthesis of factual information that states a relationship between two or more concepts” (McKinney & Edgington 1997, pp. 78–79). Marschall & French (2018, p. 18) add that ‘Generalizations transfer across contexts and situations. They are written as truths, and therefore may require qualifiers such as *often*, *can*, or *may*’. A generalisation can be used by students to apply their knowledge to situations they have not experienced, and so create new understandings.

Table 1: Three taxonomies of cognitive demand

Revised Bloom taxonomy of the cognitive process	Marzano’s taxonomy	Biggs’ SOLO taxonomy
Remember Recognise Recall	**Retrieval** Recognise Recall Execute	**Unistructural** (student includes one relevant aspect) Identify Name Follow simple procedure
Understand Interpret, Exemplify, Classify, Summarise Infer, Compare, Explain	**Comprehension** Integrate Symbolise	**Multistructural** (student includes several relevant independent aspects) Combine, Describe, Enumerate Perform serial skills, List
Apply Execute Implement		
Analyse Differentiate Organise Attribute	**Analysis** Match Classify Analyse errors Specify Generalise	**Relational** (student integrates information into a structure) Analyse, Apply, Argue, Compare/contrast Criticise, Explain causes, Relate, Justify
Evaluate Check Critique Create Generate Plan Produce	**Knowledge utilisation** Make decisions Solve problems Experiment Investigate	**Extended abstract** (student generalises the structure to a new domain) Create, Formulate, Generalise Hypothesise, Reflect, Theorise

Sources: Krathwohl, 2002; Dubas & Toledo, 2016; Biggs, 2019.

A focus on geography's major concepts, such as place, space, environment and interconnection, underpins the content of the Australian Curriculum: Geography. These concepts should be explicitly incorporated into teaching, learning and assessment programs, because they describe geography's ways of thinking and deepen students' understanding of the subject. For example, they guide the questions that geographers ask, the methods they use to organise and analyse information, the explanations they might test, the structures and patterns they look for, the ways they think about problems and search for answers, and the criteria they use to evaluate these answers. They are what makes geography *geographical*, and students should finish the unit with a better understanding of how the underpinning concepts can be applied at a range of scales, in response to a variety of questions and from different perspectives. The importance of these concepts is also highlighted in the *Professional standards for accomplished teaching of school Geography* (AGTA, n.d.). Standard 1: Knowing geography and the geography curriculum, Element 1.1 is "know the breadth and depth of the academic discipline including its concepts, skills, values and understandings", while Standard 3: Developing geographical thinking and communication, Element 3.4 is "provide students with varied contexts through which to construct a deep understanding of geographical concepts and use case studies to give support to the subject's breadth and depth".

Powerful knowledge

We also want to show teachers how focussing on higher order thinking will help them to teach powerful geographical knowledge. The concept of powerful knowledge was introduced into school educational debates over a decade ago by Michael Young, a British sociologist of education (Young, 2008). He contends that the main purpose of schools is to teach knowledge that enables students to understand and think beyond the limits of their own experience, and he describes such knowledge as *powerful*. The quotations below explain what makes this knowledge powerful:

> Powerful knowledge refers to what the knowledge can do or what intellectual power it gives to those who have access to it. Powerful knowledge provides more reliable explanations and new ways of thinking about the world and . . . can provide learners with a language for engaging in political, moral, and other kinds of debates. (Young, 2008, p. 14)

> "Powerful knowledge" is powerful because it provides the best understanding of the natural and social worlds that we have and helps us go beyond our individual experiences (Young 2013, p. 196)

> Knowledge is 'powerful' if it predicts, if it explains, if it enables you to envisage alternatives. (Young 2014, p. 74)

Powerful knowledge, therefore, provides students with ways of analysing, explaining, predicting, evaluating, and thinking about the world. These powers are very similar to those in the list of higher order thinking skills in Table 1, which shows that the two can be developed together. They are discussed below, along with an explanation of how they can be illustrated and taught through the content in the Biomes and Food Security unit, and how they contribute to higher order thinking.

The discussion also includes some comments on the way the unit is presented in the textbooks produced by the four major Australian publishers for the Australian Curriculum (Oxford University Press, Cambridge University Press, Pearson and Jacaranda). This is designed to draw attention to ways that the content in these textbooks could be extended by teachers.

Explaining and analysing

The Biomes and Food Security unit has many examples of ways of explaining, and here we focus only on those that apply geographical concepts. Below are some examples of the ways that concepts can be used in the Biomes unit to understand, explain and analyse, and therefore to use higher order thinking skills. Michael Young would argue that the knowledge that enables students to understand and explain phenomena or events, particularly those that are beyond their personal experience, is powerful knowledge.

Place

In the unit the application of the concept of place is imperative to being able to understand the link between where a biome is located and what it is able to produce. For example, although the concept of place underpins key understandings from the content descriptions across the whole unit, particular emphasis on place can be illustrated in the following content description: *Environmental, economic and technological factors that influence crop yields in Australia and across the world*. When explaining regions with particularly high crop yields, or evaluating the food production potential of northern Australia, we must examine the distinctive characteristics of particular regions, or places. For influences on crop yields, students could look for the common factors in regions with high yields that might explain their productivity, and the curriculum has suggestions on what these might be. In contextualising crop yields to Australia, students could use their knowledge of agriculture in other regions of Australia to evaluate the potential of northern Australia, and the likely problems that might be encountered. Investigating the differences between places is a very geographical way of thinking, but as in none of the textbooks is this use of the concept of place mentioned there is an opportunity for teachers to extend their content.

Scale

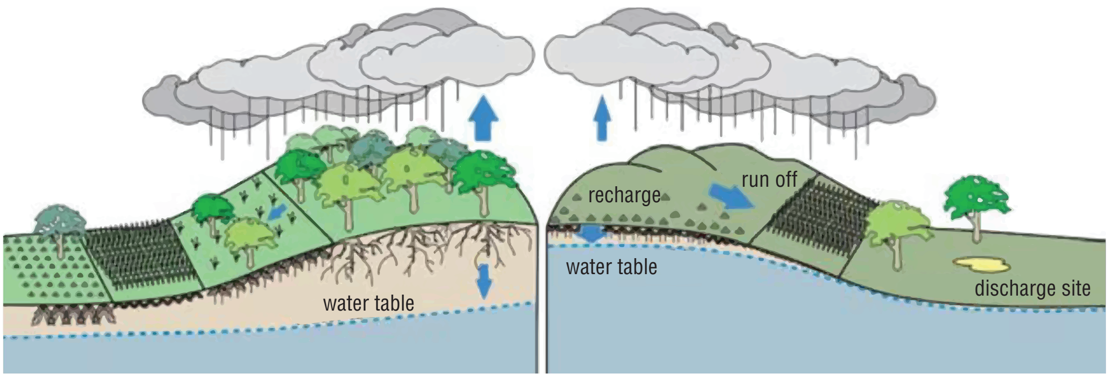
The method of testing relationships by analysing them at different spatial scales comes from the concept of scale, and it is important because different explanatory factors can be involved at different scales. In the Biomes unit, the analysis of scale can be emphasised in the following content description: *Distribution and characteristics of biomes as regions with distinctive climate, soils, vegetation and productivity,* where the production of plant matter as the basis of agriculture, is first analysed at the scale of major biomes, where temperature and precipitation are the important variables. Agricultural yields are then analysed at a larger scale, where soils and water resources modify the effects of temperature and precipitation. Students should understand that this is an analytical use of scale.

Interconnection

The concept of interconnection is fundamental to explanation in geography, because causal relationships are about the connections between causes and effects. These connections involve processes or mechanisms that seek 'to show how – by what means, through which networks – particular outcomes materialize' (Gregory et al., 2009, p. 586). Systems are phenomena linked through flows of energy, matter and information, and the second content description in the Biomes unit: *Human alteration of biomes to produce food, industrial materials and fibres, and the use of systems-thinking to analyse the environmental effects of these alterations*, suggests systems thinking can be used to analyse the effects of the changes to the environment made by humans to produce food and other products. Some textbooks explain how ecosystems are structured, but only one (by Cambridge University Press) explains that ecosystems are an example of a system, and then only briefly. None of the texts lists *systems* in their index. There is an opportunity here to introduce students to systems thinking as a way to understand the relationships between phenomena, and the processes of environmental change.

An example of the application of systems thinking that is very relevant to the Biomes unit is salinisation in Australia. Such an application is appropriate to use when covering the following content description: *Challenges to food production, including land and water degradation, shortage of fresh water, competing land uses and climate change, for Australia and other areas of the world.* Figure 1 shows the changes that can occur when native vegetation is cleared in places where the groundwater is naturally saline. The situation can be described as a system because of the interconnections between vegetation, evapotranspiration, the volume of water penetrating into the soil, and the level of the water table. When the native vegetation, with its deep roots, is removed all the other variables in the system change, as explained in the figure.

Figure 1: The causes of dryland salinity



Trees, deep-rooted perennials and native vegetation use most of the water that enters the soil, and the large blue arrow pointing upwards represents their evapotranspiration into the atmosphere. The result is limited water flow below the plant root zone, represented by the small blue arrow pointing downwards.

Removing native vegetation and growing shallow-rooted annuals reduces evapotranspiration into the atmosphere (the small blue arrow pointing upwards), and increases the flow of water to the groundwater system (the large blue arrow pointing downwards). The result is that the water table rises and brings salt to the root zone and the soil surface.

Source: Podmore 2009.

Generalising

Generalisations, as noted earlier, synthesise concepts into statements of relationships. They can be powerful because they help students make sense of a lot of information, and so increase their understanding. More importantly, they are powerful because they enable students to apply what they have learned from the study of one set of factual relationships to new situations that they have not encountered before. This enables them to ask appropriate questions, make sense of contexts beyond their experience, and increases their ability to solve problems. Generalisations can be especially powerful if they include explanation or can be used to predict. For example, from their study of the Biomes unit students might be able to appreciate the power of a generalisation such as this:

> Because of the interconnections between the components of the biophysical environment, change in one component may produce change in others. The subsequent changes may be experienced in the same place as the initial change, and/or in different places.

This generalisation could be developed from a study of the causes of salinisation described above, and then used as a framework to analyse the likely outcomes of continued land clearing for agriculture in northern Australia. Note that the generalisation adds the concept of place to that of interconnection, which makes it distinctly geographical.

Evaluating

This higher order thinking skill is, first, about the ability of students to evaluate claims about knowledge, by assessing the accuracy and soundness of information, arguments and opinions, including their own. This is a high order intellectual task, and to do it students need to know something about the ways knowledge is created, tested and assessed. The Biomes unit provides some very good opportunities to explore these ways by asking the question: how do we know? For example:

- How do we know what the future population of the world might be?
- What is the evidence for the harmful effects of genetically modified, or GM, foods?
- How do we know that vegetation clearance can cause salinisation?
- How do we know what the effects of future climate change on food production might be?

Questions such as these make students examine the methods used to find answers to some important and difficult problems, and to think about why different people produce different answers. For example, a recent book argues that the projections of the future population of the world by the United Nations are much too high, and explains why (Bricker & Ibbitson, 2019). Which projection is chosen makes a big difference to the assessment of future food security.

A second aspect of evaluation is thinking about the implications of what one is learning about a topic. For example, the Biomes unit asks students to think about the sustainability of food production methods, and about future threats to sustainability, yet the textbooks have little explanation of how to evaluate this. There is an opportunity here to give students a much deeper understanding of sustainability, and of how to make the concept operational. Some suggestions can be found in Maude (2014) which proposed this test of sustainability for renewable resources:

> To be sustainable, renewable resources should be extracted at or below their rates of renewal, and in ways that do not reduce the productive capacity of the environment.

This tells students to assess the sustainability of timber production, for example, by whether timber is being extracted above the rate at which it is being renewed through growth or new planting, and of agricultural production, by whether the methods used are degrading the productive capacity of the land. The curriculum draws the attention of students to several examples of land degradation.

Ways of thinking

The actions described by the verbs in Table 1 all involve individual ways of thinking. Young's idea of powerful knowledge as providing "new ways of thinking about the world" offers a much broader view of higher order thinking, because these ways of thinking influence a number of these actions. Geography's ways of thinking are embedded in its major concepts of place, space, environment and interconnection. These concepts influence the questions geographers ask, the methods they use to answer them, the explanations they explore, and the ways they evaluate their findings. However, in the textbooks we examined, while the major concepts specified in the curriculum are explained in the introductory pages, with the limited exception of two texts (both by Oxford University Press) they are scarcely referred to in the rest of each book. Here is another opportunity for teachers to extend the texts to teach geographical ways of thinking.

There are many opportunities in the unit to show how the topic being discussed illustrates a concept, or could be further explored by applying a concept. For example, the concept of interconnection can be illustrated by ecosystems, by the environmental changes caused by agriculture, by the links between the various causes of food insecurity, and by trade in agricultural products.

The unit also provides opportunities to develop student understanding of the concept of environment. One of the dimensions of the concept could be described in this way:

> Humans are dependent on the biophysical environment for their survival. It supports and enriches human life by providing raw materials and food, recycling and absorbing wastes, maintaining a safe habitat and being a source of enjoyment, inspiration and identity.

This statement emphasises our dependence on the environment, and therefore the fundamental importance of preserving its ability to support human life and human welfare. The Biomes unit explores human dependence on the environment for raw materials and food in some detail, particularly as it starts with the productivity of different environments, the ways that humans have modified them to increase yields, and the threats to their productive role from land degradation, water scarcity, competing land uses and climate change. The whole unit is an extended illustration of the above statement, and could be taught as such.

Structuring the unit as an inquiry

One way to design the Biomes unit to teach higher order thinking is to structure it as an inquiry, because this will emphasise questioning, analysis, explanation, generalisation and prediction, and issues that do not have simple answers. This is not difficult, as the unit has a theme running through it that links the sections of the curriculum, and these have been arranged in a logical order. The theme is described in the title: Biomes and Food Security. This is not a unit about biomes on their own, but about biomes as the source of food and fibre. Here is a possible structure.

The overall question to be answered at the conclusion of the unit is:

> *Can the projected future population of the world be adequately and sustainably fed?*

An answer to this question can be developed in steps, each of them starting with a question, the answer to which leads to the next step and question. The major geographical concepts that can be illustrated and applied at each step are noted in brackets in the description below. The structure also includes possible generalisations that sum up each stage in the inquiry. They are included as examples, not as definitive statements, and some of them are suitable for class debate, as they can be contested.

Question 1. What is the ultimate source of our food?

Our food comes from the environment, either directly from plants or indirectly when we eat animal products. At a global scale, the production of plant matter, or biomass, depends on precipitation and temperature. It varies between biomes and is measured by net primary productivity. We need, therefore, to know what biomes are, where they are, and the effects of climate on biomass production in each major biome.

Note that the content description for this section of the Biomes curriculum, and one of its elaborations, include the terms *productivity* and *net primary productivity*. These were added to get students to think of productivity as one of the attributes of a biome or ecosystem, and of net primary productivity as a numerical way to measure it and compare biomes. Only one textbook adopted this approach.

Possible generalisations:

- The biophysical environment supports human life through the production of plant matter that supplies food, fibre and industrial materials. (one dimension of the concept of environment);
- The production of plant matter is determined by temperature and precipitation and varies between biomes. (concepts of environment and place);
- The production of food, fibre and industrial plant materials requires the alteration of environments, and the appropriation of biomass by humans. (concept of environment).

Question 2. What factors determine food crop yields?

Food crops are a specialised form of biomass, grown by human intervention in the environment. The next step is to examine the environmental, economic and technological factors that influence food crop yields. This is where soils and water resources modify the influence of climate, and factors such as irrigation, accessibility (concept of space), labour supply, landforms and agricultural technologies (for example, high-yielding varieties) become important. Australia is an excellent example of environmental constraints on agricultural production (for example, limitations in soil moisture, water resources and soils), as well as of innovations (such as crop breeding and conservation farming) that have overcome some of them. Note that the analysis of crop yields is at a different scale to biomes and can be used to illustrate the concept of scale.

While the curriculum specifies food crop yields, most textbooks only discuss the quantity of production of specific crops in various countries. This is a missed opportunity, because understanding yields is a step towards understanding the potential for increasing them to feed future populations (by intensification), instead of simply bringing more land under cultivation (by extensification).

Possible generalisations:

- Food crop yields are influenced at a local or regional scale by landforms, soil quality, irrigation infrastructure, labour supply, accessibility and agricultural technology, as well as at a global scale by temperature and precipitation. (concepts of environment, space and scale)
- The constraints on food production produced by environmental conditions can be reduced but not eliminated by technology and human organisation. (one dimension of the concept of environment)

Question 3. Are the methods used to produce food environmentally sustainable?

The changes to the environment required for food production have had positive effects, as they enable us to feed ourselves, and produce fibre and timber. Furthermore, some highly altered environments have been quite sustainable agricultural systems, such as in China or Bali. On the other hand, some changes have had negative effects, and some of these may be a threat to the sustainability of food production (concept of sustainability). The curriculum mentions the following changes: vegetation clearance, introduction of exotic species, drainage, terracing and irrigation, and there are others such as fertilisers, pesticides and genetically modified plants. To understand their effects on the environment it can be useful to compare the differences between natural and agricultural ecosystems in flows of nutrients and water, and in biodiversity, and the consequences of these differences. This is where ecosystems become relevant to the argument (concept of interconnection). As mentioned earlier, students also need to understand what sustainability means when applied to food production, including fishing.

Australia should be a case study of the effects of human alteration of the environment for food production, and of ways to manage any negative consequences and improve sustainability.

Possible generalisations:

- To be sustainable, renewable resources should be extracted at or below their rates of renewal, and in ways that do not reduce the productive capacity of the environment. (concept of sustainability);
- Because of the interconnections between the components of the biophysical environment, change in one component may produce change in others. The subsequent changes may be experienced in the same place as the initial change, and/or in different places. (concepts of interconnection and place);
- Agricultural methods have degraded large areas of the world's soils though erosion, acidification, contamination, salinisation, compaction and loss of organic matter. (concept of environment);
- The production of food and raw materials has increased the appropriation of biomass by humans, and reduced that available for animal life. (concept of environment);

Question 4. Can the world's biomes produce enough food to sustainably feed the projected future global population?

The answer to this question builds on material examined in questions 2 and 3, but we must first estimate the size of the projected human population, and the implications of trends in food consumption, such as the growing preference for animal products. The next step is to evaluate ways of increasing food production to the level needed to feed that population, including the differences between intensification and extensification, and the environmental sustainability of alternative methods. The curriculum also reminds us that future food production will be reduced by land degradation (soil erosion, salinity, desertification), industrial pollution, water scarcity, competing land uses (such as urbanisation), and climate change, if these challenges cannot be managed.

An appropriate case study is Australia's potential to increase its contribution to future world food production. Can production be increased, both through technological innovations and agricultural production in northern Australia? Will this increase outweigh the effects of population growth in Australia on local food consumption, and therefore on food exports? What is the environmental sustainability of the different methods of increasing agricultural production in Australia?

None of these topics and questions has obvious answers, and they provide opportunities for students to discuss, evaluate evidence and validity of alternative opinions, debate, and reach conclusions that they can defend. Predicting the future population of the world, and of individual world regions, is one such topic.

Generalisation:

- Intensification may be a more environmentally sustainable way to increase world food production than extensification, but the capacity of either to produce food in the future faces challenges from land degradation, water scarcity, competing land uses and climate change. (concepts of sustainability and environment).

Question 5. Will increased food production provide food security for all people?

An elaboration in the curriculum suggests examining how poverty, food wastage, government policies or trade barriers could also affect future food security. This part of the unit provides great opportunities for students to discuss, debate and argue over alternative answers, building on what they have studied so far. There is no one simple answer to the question.

Generalisation

- Future world food security is threatened more by poverty, conflict, water scarcity, climate change and unsustainable agricultural methods than by the growth of population. (concept of environment)

The structure outlined above provides a framework that will help teachers decide what needs to be taught, and what doesn't, because some textbooks have material that is not specified in the curriculum. For example, the focus in the biomes sections of the curriculum is very much on their productivity, because the biomass they produce is the source of food and fibre. This should be the theme of these sections, but some texts have material on ecosystems that does not fit the theme, such as on threats to biomes. This content would be appropriate in a purely physical geography text, but in the Biomes unit it results in an overload of information. The structure will also help teachers to decide when to illustrate and develop an understanding of a concept, what sorts of generalisations might be discovered, how the content of the unit can be organised around questions and inquiry, ways to encourage debate, and how to integrate the teaching of skills with the content being studied. All of this will contribute to higher order thinking. The structure is shown diagrammatically in Figure 2, using generalisations (syntheses) to describe each step.

Figure 2: A possible structure for the Biomes unit

The biophysical environment supports human life through the production of plant matter that supplies food, fibre and industrial materials.

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The production of plant matter is determined by temperature and precipitation, and at a global scale varies between biomes.

↓

Food crop yields are influenced at a local or regional scale by landforms, soil quality, irrigation infrastructure, labour supply, accessibility and agricultural technology, as well as at a global scale by temperature and precipitation.

↓

The changes to environments caused by current methods of agriculture have both positive and negative effects on the sustainability of food production.

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Intensification is likely to be a more sustainable way to increase world food production than extensification, but the capacity of either to produce food in the future faces challenges from land degradation, water scarcity, competing land uses and climate change.

↓

Future world food security is threatened more by poverty, conflict, water scarcity, climate change and unsustainable agricultural methods than by the growth of population.

Conclusion

In this article, we have explained why higher order thinking is important, and how it can be integrated with the teaching of powerful knowledge and geography's major concepts. We then proposed ways that teachers could use the content of the Biomes and Food Security unit to develop the higher order thinking of their students, and to teach some powerful geographical knowledge. We set out a way of structuring the unit as an extended inquiry, guided by a sequence of questions, in order to emphasise questioning, analysis, explanation, synthesis, generalisation, and prediction. Structuring the unit in this way should make teaching easier, because the questions provide a guide to what is relevant and what is not, and a focus for each step in the inquiry. Students, on the other hand, should find the unit easier to comprehend because of its clear structure, while the generalisations they develop will enable them to synthesise factual information into powerful statements of relationships and understandings. If geography's major concepts have been fully applied to the content of the unit, students should also understand what is *geographical* about it, and why these concepts are the foundation of geographical thinking and the distinctiveness of the subject. At the same time they will have learned some important information about the environmental basis of food production, and agricultural methods and their sustainability, particularly in Australia. These are topics that, in the Australian curriculum, are only taught in geography.

References

AGTA (n.d.). *Professional Standards for the Accomplished Teaching of School Geography*. Retrieved from www.agta.asn.au/files/Professional%20Standards/geogstandards.pdf on 12 August 2019.

Beresford, Q. (2001). Developmentalism and its environmental legacy: the Western Australia Wheatbelt, 1900–1990s. *Australian Journal of Politics, & History*, *47*(3), 311–460.

Biggs, J (2019). *SOLO taxonomy*. Retrieved from http://www.johnbiggs.com.au/academic/solo-taxonomy/

Birch, G. (2014). Biomes and food security: some practical lesson ideas for the new national curriculum unit. *Interaction*, *42*(4), 25–27.

Bricker, D., & Ibbitson, J. (2019). *Empty planet: the shock of global population decline*. London: Robinson.

Carey, R., & Sheridan, J. (2017). Australia's city food bowls: fertile ground for investigating biomes and food security. *Geographical Education*, *30*, 16–23.

Collins, R. (2014). Skills for the 21st Century: teaching higher-order thinking. *Curriculum & Leadership Journal, 12*(14).

Chaffer, L. (2019). Sustainable biomes: an introduction. *Geography Bulletin*, *51*(1), 8–14.

Dubas, A., & Toledo, S. A. (2016). Taking higher order thinking seriously: Using Marzano's taxonomy in the economics classroom. *International Review of Economics Education*, *21*, 12–20.

Gregory, D., Johnston, R., Pratt, G., Watts, M.J., & Whatmore, S. (2009). *The dictionary of human geography* (pp. 586–587). Chichester: Wiley-Blackwell.

Huckle, J. (2019). Powerful geographical knowledge is critical knowledge underpinned by critical realism. *International Research in Geographical and Environmental Education*, *28*(1), 70–84.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: an overview. *Theory Into Practice*, *41*, 212–218.

Lewis, A., & Smith, D. (1993). Teaching for higher order thinking. *Theory into Practice*, *32*(3), 131–137.

Marschall, C., & French, R. (2018). *Concept-based inquiry in action: strategies to promote transferable thinking*. Thousand Oaks: Corwin.

Maude, A. (2014). Sustainability in the Australian curriculum: geography. *Geographical Education*, *27*, 19–27.

Maude, A. (2016). What might powerful geographical knowledge look like? *Geography*, *101*, 70–76.

Maude, A. (2017). Applying the concept of powerful knowledge to school geography. In C. Brooks, G. Butt, & M. Fargher (Eds.), *The power of geographical thinking.* Springer, Cham, (pp. 27–40).

McKinney, C. W., & Edgington, W. D. (1997). Issues related to teaching generalizations in elementary social studies. *The Social Studies*, *88*(2), 78–81.

Podmore, C. (2009). Dryland salinity – causes and impacts. *Primefact* 936.

Rostolis, R. (2014). Biomes and food security: a teaching and learning plan. *Interaction*, *43*(2), 18–27.

White, J. (2018). The weakness of 'powerful knowledge'. *London Review of Education*, *16*(2), 325–335.

Young, M. (2008). From constructivism to realism in the sociology of the curriculum. *Review of Research in Education*, *32*, 1–32.

Young, M. (2010). The future of education in a knowledge society: The radical case for a subject-based curriculum. *Journal of the Pacific Circle Consortium for Education*, *22*, 21–32.

Young, M. (2013). Powerful knowledge: An analytically useful concept or just a 'sexy sounding term'? A response to John Beck's 'Powerful knowledge, esoteric knowledge, curriculum knowledge'. *Cambridge Journal of Education*, *43*, 195–198.

Young, M. (2014). Powerful knowledge as a curriculum principle. In M. Young, D. Lambert, C. Roberts, & M. Roberts (Eds.), *Knowledge and the future school: Curriculum and social justice* (pp. 65–88)., London: Bloomsbury Academic.

Endnotes

1. For explanations and critiques of powerful knowledge see Maude (2016 and 2017), Huckle (2019), and White (2018).
2. For a cautionary history of resistance to knowledge about the causes of salinisation in Western Australia, see Beresford (2001).
3. For other ideas on teaching this unit see Birch (2014), Carey and Sheridan (2017), Chaffer (2019), and Rostolis (2014).