High School Teachers' Appropriation of an Innovative Curriculum in Bioinformatics

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Abstract

One of the goals of curriculum developers is to provide learners with opportunities to engage in activities that resemble authentic scientific research. A learning environment (LE) aimed at introducing bioinformatics into a high-school biotechnology majors curriculum through engaging learners in authentic research practices served as the context for this study. A teachers' program aimed at establishing a community of biotechnology teachers who collaborate in implementing the LE was established. One of the goals of the teachers' program was to design an assessment tool for the LE. In this study, we examined how the teachers designed the assessment tool, as a means of probing their knowledge and beliefs in adopting contemporary scientific research into their classroom. The analysis of the assessment tool revealed questions that require the use of conditional knowledge, which is at the heart of performing authentic scientific research. Most of these questions called for coordination between various scientific reasoning practices. The teachers perceived research as combining laboratory experiments and bioinformatics approaches. Thus, the tool represents characteristics of authentic modern scientific research and the teachers' appropriation of the new bioinformatics curriculum, by extending its roots to the 'traditional' curriculum.

Keywords: Authentic science education, Bioinformatics curriculum, Teachers' development program, Assessment, Domain-specific knowledge.

Introduction

One of the fundamental goals of curriculum developers is to provide learners with opportunities to engage in scientifically authentic practices, namely practices that resemble authentic scientific research as they are carried-out by the scientific community (Buxton, 2006). This perspective on authenticity is aligned with both the Western scientific canon and the canon for science education standards in the US (National Research Council [NRC], 1996, 2011), Europe (European Union, 2006) and elsewhere (Yarden & Carvalho, 2011). Such practices represent important discipline-specific aspects of science, may therefore enhance cultivation of students' scientific habits of mind and can contribute to the contextualized understanding of how scientific knowledge is acquired, evaluated, and developed (Samarapungavan, Westby, & Bodner, 2006); to develop a deep understanding of scientific knowledge (Abrams, 1998; Lee & Songer, 2003); and to invoke the reasoning that scientists employ and the epistemology underlying authentic inquiry (Chinn & Malhotra, 2002).

The overall greater complexity of authentic scientific research requires coordination between various intervening events of the scientific practice (Chinn & Malhotra, 2002; Falk & Yarden, 2009), continuous application of conditional knowledge and coordination of declarative and procedural knowledge, while reasoning scientifically and making decisions (Gelbart & Yarden, 2011). Declarative knowledge has been defined as knowing "what" the factual information is, procedural knowledge as knowing "how" to use this knowledge in certain processes or routines, and conditional knowledge as understanding "when and where" to access certain facts or employ particular procedures (Alexander & Judy, 1988). Usage of conditional knowledge, and coordination of facts, procedures and strategies, are not typical of regular school tasks and rarely appear in school learning materials (Chinn & Malhotra, 2002; Yarden, 2009).

The Emergence of Bioinformatics

Biology in the 21st century is being extended from a purely lab-based science to an information-aided science. Bioinformatics is an emerging interdisciplinary field that enables management and mining of biological data. Biological data is stored and organized in computerized databases, and can be viewed and analyzed using specialized tools. The evolving bioinformatics approach intertwined with experimental technologies has revolutionized modern biology (Attwood, Gisel, Eriksson, & Bongcam-Rudloff, 2011).

While bioinformatics is increasingly important in modern life sciences, it plays almost no role in high-school science classes. To keep science curricula current, considerable resources are now being devoted to integrating this exciting field into science classrooms (Gallagher, Coon, Donley, Scott, & Goldberg, 2011; Gelbart & Yarden, 2006; Lewitter & Bourne, 2011; Wefer & Sheppard, 2008).

We recently developed a web-based learning environment (LE) (Machluf, Dahan, Shpalter-Avidan, Mitchel, & Yarden, 2011) that is aimed at introducing bioinformatics into a high-school biotechnology majors curriculum in Israel. Learners are invited to take part in five authentic inquiry activities in biotechnology using eight bioinformatics tools and databases (see http://stwww.weizmann.ac.il/menu/personal/anat_yarden/abstracts/Bioinformatics.pdf). The activities were developed based on primary research articles selected according to the relevance of the scientific context to students' interests; a clear biotechnological application; and use of a variety of bioinformatics tools and databases that are suitable for high-school students' cognitive level. The selected bioinformatics tools are basic yet fundamental; they are commonly used by scientists and enable acquisition of central bioinformatics principles and approaches.

Teachers' Professional Development

We believe that successful implementation of bioinformatics as an elective topic in the biotechnology syllabus is greatly dependent on the teachers, who should become agents of change (Fullan, 1993). Therefore, a teachers' professional development program was established during the 2010-11 academic year. The main rationale of this program was to develop teachers' identities as reform-minded teachers, pioneers at the forefront of high-school bioinformatics education, who recruit their knowledge and experience to mutually design and develop bioinformatics instructional means and assessment tools.

Research Goal and Questions

This study examined how high-school biotechnology teachers design and develop an assessment tool for an innovative LE in bioinformatics, as a means to probe their knowledge and beliefs in adopting contemporary scientific research into their classrooms. Specifically, we asked:

(I) What are the characteristics of the assessment tool developed by the teachers?

(II) What was the teachers' rationale behind the development of the assessment tool?

Research Design and Method

Research Population

Four highly qualified in-service biotechnology teachers, from four different high schools across the country, with only limited knowledge in bioinformatics but with experience in implementing innovative learning materials and preparing students for the matriculation exams in biotechnology, were selected to participate in the teachers' professional development program, which served as the context for this study (Table 1).

Table 1. Participants characteristics

Teacher	Gender	Degree	Years of biotechnology teaching experience	Experience in writing matriculation exams	Other duties
1	Male	Ph.D.	30 (13)	Yes	
2	Female	Ph.D.	31 (14)	Yes	National advisor
3	Female	M.Sc.	24 (10)	No	Regional advisor
4	Male	M.Sc.	6 (6)	No	

Research Context

In the program, most of the teachers' time (37 meetings, 8 hours each) was devoted to workshops in bioinformatics. These workshops introduced the teachers to the bioinformatics world of research and education. First, emphasis was placed on acquisition of theoretical content knowledge and experiencing firsthand practical skills in using bioinformatics tools and databases. They then became fully familiarized with the LE and its activities, prepared teaching materials, instructed their own students while enacting LE activities, and analyzed and reflected on their experiences. Then, over three sessions, teachers collaboratively designed, developed and refined an assessment tool that could serve as a model for the national bioinformatics matriculation examination.

Research Tools and Data Analysis

To study the characteristics of the assessment tool developed by the teachers, and to uncover tacit knowledge and their perception of bioinformatics research, the questions embedded in its three versions of the assessment tool were classified based on the following criteria:

I) Domain-specific knowledge (following (Alexander & Judy, 1988)): questions were categorized according to the type of knowledge required to answer them, namely *declarative*, *procedural*, or *conditional* knowledge.

II) Scientific reasoning (following (Chinn & Malhotra, 2002)): *research questions*—dealing with and coordinating research questions, *methods*—selecting methods and examining their suitability to the research questions, *results*—analyzing the results, and *theoretical explanations*—generating explanations and conclusions.

III) Scientific approach: questions that stem from a *biological* approach, *bioinformatics* approach, or a combination of *both*.

All of the questions were classified independently by two researchers, specialists in the fields of bioinformatics and science teaching, and discussed until 100% agreement was achieved.

To uncover teachers' rationale behind the development of the assessment tool, they were interviewed at the end of the year; the interviews were recorded, transcribed, and analyzed bottom-up following Shkedi (2003). Shortly, data were divided into different themes, while allowing recurrent categories and ideas about the design and development process to emerge from the data. Key themes and categories as well as representative quotes are described.

Results

Characteristics of the assessment tool

The questions embedded in the assessment tool were analyzed according to the three criteria. The general characteristics of the three versions of the assessment tool were similar, therefore only the analysis of the last version is presented.

The frequency of questions (Table 2) that require the use of declarative knowledge was half that of the questions requiring either procedural or conditional knowledge. Similarly, the frequencies of questions dealing with either a biological approach or a bioinformatics approach were almost equal within each session whereas the frequency of questions dealing with a combined approach was about twofold lower. Analysis of the frequencies of questions dealing with scientific reasoning revealed that most deal with results (57%), while much fewer deal with the research questions (14%).

Table 2. Frequencies of questions embedded in the assessment tool classified according to three criteria: Domain-specific knowledge, Scientific approach and Scientific reasoning

Scientific criteria	Categories	Total number of questions percentage)[b] (n=28)
Domain-specific knowledge	Declarative	5 (18%)
	Procedural	11 (39%)
	Conditional	12 (43%)
Scientific approach	Biology	12 (43%)
	Bioinformatics	11 (39%)
	Biology and Bioinformatics	5 (18%)
Scientific reasoning[a]	Research questions	4 (14%)
	Methods	7 (25%)
	Results	16 (57%)
	Theoretical explanations	8 (29%)

[a] The sum of questions classified as scientific reasoning is above the overall number of questions due to multiple attributions of several questions.

[b] The number of questions within each category and their percentage of the total number of questions is presented.

Questions dealing with *results* called mainly for procedural knowledge and to a lesser extent for conditional knowledge (Table 3). Questions dealing with either *research questions* or *methods* called almost exclusively for conditional knowledge (Table 3). In questions calling for *theoretical explanations*, a non-significant over-representation of questions requiring the use of conditional knowledge was observed (Table 3). While most of the questions that required the use of declarative knowledge (4/5=80%) were not assigned to any of the scientific reasoning categories, majority of the question requiring the use of conditional knowledge (7/12=58%) were assigned to multiple scientific reasoning categories.

Table 3. Distribution of questions calling for a particular scientific reasoning according to the domain-specific knowledge criterion

Scientific reasoning	Domain-specific knowledge Declarative (n = 5)	Procedural (n = 11)	Conditional (n = 12)
Research questions	0	0	4*
Methods	0	1	6*
Results	1	10	5**
Theoretical explanations	1	2	5
Not assigned to any scientific reasoning category	4	0	0
Assignment to a single scientific reasoning category	0	9	5
Assignment to multiple scientific reasoning categories	1	2	7

*$0.01 < P < 0.05$; ** $0.001 < P < 0.01$

Teachers' rationale

Teachers perceived their 'mission' as "to speak on behalf of our students and to adapt the learning materials and assessment tool to their level" while making it "relevant to students…challenging yet not frightening" (Teacher#2). The assessment tool's format was developed by the teachers with the aim of demonstrating "a clear [biotechnological] research approach, following the sequence of the [original] research, and making clear the rationale behind this sequence" (Teacher#1). The teachers particularly emphasized their attempts to integrate questions calling for application of prior knowledge in biotechnology, mainly key concepts in the biotechnology curriculum, and general inquiry skills while using the bioinformatics tools: "It's great that we could integrate scientific concepts, connect between something in biochemistry like an enzyme activity, and what we see using the [bioinformatics tool] Jmol" (Teacher#1). They also tried to include general scientific skills: "We peppered the questions with more skills such as reading graphs…that are learned in the [school] lab" (Teacher#1). In the same line, the teachers referred to the importance of selecting bioinformatics tools that match the biotechnology curriculum and those that are central to it.

A similar representation of questions calling for either biological or bioinformatics approaches, as well as inclusion of questions that coordinate both approaches, reflect teachers' acquired perception of a research approach as combining laboratory experiments and computational analysis. This can be considered another aspect of authentic modern scientific research. Furthermore, this coordination may reflect teachers' desire to adapt the new curriculum by linking it to the existing 'traditional' one. It was explained as "the whole issue here is to connect the biological approach and what you get by using the bioinformatics tools and biological knowledge!…the integration just jumped out at me!" (Teacher#2). Another teacher claimed that "actually we should place a hyphen connecting bioinformatics to biology" and added that "integration should be performed between the biological part, which is seemingly more external and extrovert, and the understanding of [bioinformatics and research] processes....the synapse [of biology and bioinformatics] should be discussed" (Teacher#1). Another teacher explained that "there is a need to connect what you find using the [bioinformatics] tools with the biological knowledge that is deeply established in us…this is the way I'd like to teach it in class" (Teacher#3) as the other teachers nodded in agreement.

While reflecting on the process of developing the assessment tool, the teachers concurred that it was a long and enjoyable journey, during which they realized how difficult the process of developing authentic research-based materials is, while at the same time learning how to develop such a tool, what and how to assess, and by what means to analyze and classify the questions. Importantly, in the development of the assessment tool, each teacher could "express one's creativity, motivation, desire to contribute, and innovative ideas" (Teacher#2).

Discussion

The analysis of the questions embedded in the assessment tool revealed that the teachers had integrated a considerable number of questions that require the use of conditional knowledge, a type of knowledge which is at the heart of performing authentic scientific research. Most of these questions require the coordination of multiple scientific reasoning practices. Similar representation of questions stemming from either biological or bioinformatics approaches, as well as inclusion of questions coordinating both approaches, reflected teachers' acquired perception of a research approach as combining laboratory experiments and bioinformatics. These features indicate that the assessment tool represents characteristics of modern authentic scientific research (Chinn & Malhotra, 2002; Falk & Yarden, 2009; Gelbart & Yarden, 2011), namely the way scientific knowledge is created and evaluated in the life sciences today. In this view, the assessment tool represents the teachers' appropriation of the new curriculum in bioinformatics, through adoption of its authentic scientific research characteristics, and through expansion of its roots to the 'traditional' curriculum. The assessment tool was in accordance with the goals of the bioinformatics curriculum; at the same time it comprehensively integrated and presented unique features of the bioinformatics field (Wefer & Anderson, 2008).

The design and development of an assessment tool for an innovative curriculum by teachers can serve as an appropriate means of linking and integrating contemporary and pioneering materials into existing scientific curricula, to expand teachers' knowledge. It may also have affected their orientation toward educational reforms and professional development programs, as one teacher noted "I'm interested in being part of future programs of developing [educational] initiatives…from the perspective of my standards, I always want to be at the forefront, I do not want to lag behind…this is how I see myself!" (Teacher#4). Thus, it is recommended that key steps of the design and development of assessment tool or learning materials be integrated into professional development programs or training workshops for teachers.

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