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ABSTRACT

This paper discusses the use of rubrics in a preservice science methods course. Section 1 explains that a rubric is a standard of performance for a defined population. It is also the guidelines laid out for judging student work on performance-based tasks. In science education, it is a purposeful and appropriate construct that articulates varying levels of proficiencies that are congruent with the field of science education. Section 2 discusses the rationale for using rubrics. Rubrics, as one of several alternative assessment options in science teacher education courses, are congruent with professional recommendations for assessment. They can indicate student progress throughout the course; help students become self-directed, reflective practitioners; and provide the instructor with information about the effectiveness of curriculum and instruction and a chance to inquire into aspects of effective practice. Section 3 discusses the use of rubrics in one science methods course. Section 4 examines the benefits and detriments of using rubrics based on the science methods course experience. Benefits include reflective practice by the students and instructor and use of rubrics in students' own classes. Detriments relate to issues of time and the clarity of written criteria within a rubric. (Contains 33 references.) (SM)

Rubrics: Design and Use in Science Teacher Education

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Rubrics: Design and use in science teacher education

Science teachers at various academic levels are exploring the use of rubrics in their science classes (Jensen, 1995; Liu, 1995; Lundberg, 1997; Nott, Reeve, & Reeve, 1992; Radford, Ramsey, & Deese, 1995; Shaka & Bitner, 1996). From the middle school classroom to the university science laboratory, rubrics have been used to assess students' laboratory skills, students' problem solving abilities, or students' performances. Within each context of use, the clearly stated standards regarding performance--the basis of a rubric--have assisted science teachers in clarifying their expectations to students (Lui, 1995; Nott, et al., 1992) and monitoring their students understanding about science topics (Jensen, 1995; Lundberg, 1997). These qualities, the clarification of performance standards and the articulation of evaluation criteria to students, along with an increased knowledge about students' growth, are congruent with the recommendations for assessment in the National Science Education Standards (NRC, 1996).

Similar to science teachers, educators of science teachers are also exploring the use of rubrics (or similar scoring schemes) in their own programs and classes (Finson, 1994; Herr, Holtzer, Martin, Esterle, & Sparks, 1995; Moscovici & Gilmer, 1996). Inservice science teachers are learning about rubrics as they are involved in their on-going professional development. Workshops, institutes, or university/college courses are common places for inservice teachers to experience rubrics that can be applied to their instruction or to evaluate their own practice (see Ford, 1994; Pizzini, 1996; Yager, Kellerman, Liu, Blunck, & Veronesi, 1993). Pre-service science teachers are also now encountering rubrics in both education and science courses (Luft, Ebert-May, Eslamieh, & Buss, 1997). While little has been written about the use of rubrics in pre-service science education, the National Science Education Standards (NRC, 1996) prescribes guidelines for assessment practices that should be utilized by those involved in the professional development of science teachers. Rubrics are congruent with these stated types of assessment experiences.

This paper discusses the use of rubrics in one pre-service science teacher education course -- a science methods course. It begins by defining the term rubric and providing a rationale for using rubrics, continues with a discussion on how rubrics were used in one science methods course, and then concludes with comments about the possible benefits and detriments of using rubrics in a science education courses. The intent of this paper is to share my experience with rubrics, and to contribute to the literature that pertains to the use of rubrics in science teacher education.

Towards a definition of "rubric"

The science education community has a variety of ways to define the term rubric. The National Science Education Standards (NRC, 1996), a document to guide science education, states that a rubric is "a standard of performance for a defined population (p.93)." Others who are interested in the use of rubrics for large scale assessments may define it as "the guidelines laid out for judging student work on performance -based tasks (p.41) (McColskey & O'Sullivan, 1993)." Those who are developing rubrics for the assessment of students in their class may describe a rubric as "an established set of criteria used for scoring or rating students' tests, portfolios, or performances. A score rubric describes the levels of performance students might be expected to attain relative to a desired standard or achievement (p. 70) (Hart, 1994)." And teachers who are interested in creating an assessment to record student achievement levels, may depict a rubric as "a formalized scale that describes appropriate answers for increasing levels of accomplishment (p. 44) (Nott, et al., 1992)." Although each educator has a definition of a rubric that is congruent with their context of use, most see rubrics as being descriptions of various levels of student performance.

In addition to the variety of rubric definitions, there are a variety of recommendations for the development of rubrics. Various authors have discussed the development of the criteria within a rubric. Some authors suggest beginning the rubric by clarifying goals and standards for students. Ochs (1996), for example, proposes that a rubric should be developed to answer three questions: 1) What do we want students to know and be able to do? 2) How well do we want students to know and be able to do? 3) How will the teachers and other scorers know when the student knows it and does it well? (p.121). Others suggest beginning the development of rubric with the depiction of an acknowledged standard. For instance, the National Science Education Standards (NRC, 1996) recommends beginning the development of a rubric with a description of the performance standard for a scientifically literate person. This description should then be analyzed and divided into the different components of the response. The rubric should be further modified to consider the science experiences and the developmental level of the students. Regardless of whether the criteria for the rubric originates from the developer or from external standards, the criteria within a rubric should be sensitive to purpose, keyed to important outcomes, developmentally appropriate, meaningful and clear, feasible, and generalizable (Herman, Aschbacher, & Winters, 1993; Quellmalz, 1991).

When rubrics are developed, they can be either holistic, analytical, or a combination of both. Holistic rubrics are constructs that contain different levels of performance that describe the quality, the quantity, or both the quantity/quality of a task. This type of rubric requires that the assessor determine which level is the "best fit" for the student's project, investigation, or assignment (Luft, 1997). Figure 1 is an example of a holistic rubric. Analytical rubrics are constructs that consist of criteria that are subdivided into different levels of performance. Typically, each row begins with a cell that states the criteria to be assessed and each adjacent cell describes a different level of performance for that criteria. To increase the clarity of an analytical rubric, each criteria topic can be further divided into more concise statements, and then followed by the related performance descriptions (Luft, 1997). Figure 2 is an example of an analytical rubric. Generally, holistic rubrics contain broad descriptions about levels of performance, while analytical rubrics tend to have more specific and concise descriptions that relate to specific criteria.

In consideration of the above mentioned, I offer a modified definition for rubrics in science education: a purposeful and appropriate construct that articulates varying levels of proficiencies that are congruent with the field of science education. The construct is purposeful when it informs the student, the teacher, and other interested parties about the growth and knowledge of a pre-service science educator within a task, a performance, or an artifact. The construct is appropriate when it considers the pedagogical knowledge, the content knowledge, and the experiential levels that are relevant to the science education student within the task, performance, or artifact. And rubrics are congruent with the field of science education when they contain criteria that advance science education students towards the goals espoused by their science teacher education program. This definition pertains to science teacher education and it is the definition that is referred to in this paper.

The Rationale for the Rubric

Alternative assessments offer science teacher educators an opportunity to present more than a final grade to their students. Enacted effectively, alternative assessments can provide meaningful information to the student, the teacher, and others who are interested in the development of science teachers. The potential for alternative assessments in science teacher education can be extrapolated from Hodson's (1992) article on the assessment of practical work and from the recommendations for assessment advocated by the National Science Education Standards (1996). Although neither specifically discusses teacher education and the use of rubrics, both are relevant and applicable.

Hodson (1992) discusses the need for the assessment of practical work to be summative, formative, evaluative, and educative. Hodson contends that summative assessments should provide information about the student's level of attainment of knowledge. He concludes that summative assessments, specifically tests that measure achievement at the end of a course, are the most frequent type of evaluation found in the science classroom. Formative assessments, those which monitor student progress throughout instruction, should enable a teacher to diagnose a student's strengths and weaknesses, perceive a student's learning gains, and identify a student's misconceptions. The information gained from a formative assessment would be used to advance and direct student growth within the area being covered. An evaluative assessment would provide a teacher with information about the effectiveness of planned curriculum, and would guide the teacher in modifying additional curricular experiences. This type of assessment specifically evaluates the curriculum that students experience. And an educative assessment enhances and promotes student learning by allowing students to know how they understand science while developing specific insights into science. Hodson specifies that "educative assessment means that the assessment is part of the learning, not something additional to it (p.117)."

The National Science Education Standards (NRC, 1996) discuss how assessments and their data should be utilized by teachers. First, the Standards suggest that teachers continually assess and gather information about their students. The acquired information will ultimately inform teachers about what changes they need to enact in order to improve their instruction. Second, information from student assessments should inform and direct curricular decisions made by the teacher. This results in curriculum being developmentally appropriate, of interest to the student, and effective in producing the desired learner outcomes. Third, assessments used by teachers should encourage students to become self-directed learners. Being a self-directed learner can come from the opportunity to evaluate and reflect upon one's own work in the science classroom. Fourth, assessments should be able to provide information about a student's progress to all of the stakeholders involved in the student's education. This specifically includes frequent reports that discuss the student's attained levels of achievement. Fifth, assessments should provide teachers with an avenue to research their own practice. In addition to providing an understanding about a student in the science class, assessments should also provide a teacher with the opportunity to inquire into the effectiveness of their own practice.

Rubrics, as one of several alternative assessment options in science teacher education courses, are congruent with Hodson's (1992) and the National Science Education Standards (1996) recommendations for assessment. First, rubrics can indicate a student's progress throughout the course. As a summative assessment, rubrics can furnish a description about the level of proficiency that the student has attained by the end of the course. As a formative assessment, rubrics can provide an indication of the student's progress on various assignments encountered throughout the course. The information collected can be shared with any or all of the science education stakeholders involved in the student's development. Second, rubrics can assist science education students in becoming self-directed and reflective practitioners. For example, when students are asked to explain either verbally or in writing about their performance on a rubric, they can gain insight into how they learn or their practice (depending upon the rubric). Third, rubrics can provide information to the instructor about the effectiveness of curriculum and instruction. A student's attainment or the lack of attainment of a level of proficiency can inform an instructor about the effectiveness of the planned curriculum and the enacted instruction. Fourth, rubrics can provide an instructor with an opportunity to inquire into aspects of effective practice. By using rubrics as instruments for data collection, teacher generated questions about effective teaching practices can be answered.

Rubrics in a Science Methods Course

For three years I have been experimenting with the use of rubrics in my science methods classes. At first, I generated rubrics for class assignments in order to clarify my own expectations for my students. Later, I encouraged my students to develop their own rubrics in order to assess the quality of their own assignments. I now use a combination of rubrics that are generated by myself and my students in my science methods class.

The rubric in Figure 1 was constructed by the students in my science methods class. During our second class meeting, students were divided into groups of four and three. Each group was asked to develop a description that would portray an A, B, C, and D student in our class. In addition, I also indicated this rubric would be used during the exit conferences to help determine each student's grade. One group began by discussing attendance immediately:

Mary: An A student attends class 100% of the time.

Mark: Attending is not as important as participating. Besides, if I attend 95% of the time, does that make me a B student, even though I have demonstrated my knowledge in science education?

Jill: What if you have to miss class because of an emergency? Are your not an A student?

Wandering from group to group, I heard what my students deemed to be important in achieving an A, B, C, or D in my class. Several of the groups discussed class participation, content knowledge, and being open to new ideas. Each group appeared engrossed and attentive to the task at hand. To facilitate the already rich discussions occurring within each group, each group was encouraged to provide examples of A, B, C, and D levels of performance in the areas they were discussing. By the end of class I collected a preliminary rubric from each group.

The following class, I had students synthesize their group rubrics to form a class rubric. I began by asking students to describe an A student in our class. One member of a group provided the starting point:

Jill:	An A student participates constructively in the class.
Instructor:	What does this look like?
Mark:	We felt that it meant coming to class on time and having the assignments completed. Being prepared and ready to begin is an important part of "good studenting."
Larry:	Our group felt that participating constructively in class meant working well with others and being a team player.
Mark:	That's pretty subjective. Can you clarify that?
Rose:	I think we thought it meant listening, trying to understand, and acknowledging others' thoughts. Like "I may disagree with you, but I need to understand the point of view that you hold." When I am not sure of what you mean, I need to ask. I also need to make sure that I understand what you have said.

For the next thirty minutes we discussed the ideas that were put forth pertaining to achieving an A, B, C, or D in our class. Students asked for clarification of subjective topics, and they discussed the problems associated with the use the defined parameters of 100%, 90%, 80% and 70%. Whenever possible, I asked for specific examples of what an idea would look like or sound like.

The final thirty minutes of class were spent processing the activity. I asked specifically what students learned from the exercise. One student remarked that he "learned that assessment was more difficult that marking something right or wrong." Another student appreciated the opportunity to set their own goals for class. Another student asked why the courses in the sciences did not use rubrics, because being a student is more than a right or wrong answer. The processing of personal experiences led to a discussion about holistic rubrics and how they are used, assessments and who they should inform, and how I would be able to determine if my curriculum was supportive of their rubric.

After class I synthesized the comments that each group had contributed, and I created the class rubric (Figure 1). I later returned it to the entire class for individual revision and approval. Some students had comments, most did not.

The other type of rubric that I frequently use can be found in Figure 2. This rubric is representative of rubrics that I create to communicate the important elements of an assignment. This rubric is for a teaching assignment, Teach/Reteach, and requires that teams of students teach a lesson, assess the instruction and curricular effectiveness, modify the lesson, and then reteach the lesson to a different science class. During the Teach/Reteach lesson, science methods students are encouraged to use inquiry-based lessons and alternative assessments.

When I presented and discussed the assignment, I also revealed and described the corresponding rubric. Ultimately the purpose of the assignment was to encourage students to use the instructional methods that they are learning about (e.g. Learning Cycle, problem solving, alternative assessment, etc.), practice reflecting in and on their practice (see Baird, Fensham, Gunstone, & White, 1991; Schön, 1983), connect pedagogy and content knowledge (see Shulman, 1984), develop the language found in science education and collaborate with their peers (see Little, 1982; Rosenholtz, 1989). I attempted to develop a rubric that was congruent with my goals, and I attempted to develop a rubric that would guide students as they completed their Teach/Reteach assignment.

During the last week of Secondary Science Methods, student groups began their Teach/Reteach presentations. Each group was required to give an oral presentation that followed the guidelines in the rubric, and each student was required to turn in a more extensive individual written report on the Teach/Reteach experience. The students' presentations revealed how the corresponding rubric facilitated the students' examination of their experience.

All of the student groups successfully completed the Logistics and the Presentation portion of their assignment. The Logistics section focused on the mechanics of the experience, and mostly required that various components be accomplished throughout the Teach/Reteach experience (e.g. scheduling, video taping, etc.). The Presentation section focused on the components within each group's shared reflection. Each group attained the highest level of proficiency in both areas.

The Reflection section was written so that each group would focus on an area of their choice, and be encouraged to inquire in-depth about the topic. For example, one student noticed that she did not exhibit either wait time I or wait time II with her students (Rowe, 1987). She began to examine the type of responses she gave to her students and noticed that she frequently would direct her students to the next task or tell her students about their laboratory experience. While she still was uncertain about why she did this, she did make a conscious effort to pause after her questions and after the student's questions, and she changed the nature of her questions to be more responding (Schlitt & Abraham, 1973). Other students discussed their uneasiness with utilizing inquiry lessons, the importance of assessing prior knowledge, and motivating students in the science classroom. Most groups were able to reflect upon a few aspects of their curriculum planning or their instruction to the highest level of proficiency.

The Connections section also allowed students to focus on an area of their choice and connect theory to practice. Throughout each presentation, groups discussed constructivism, the Learning Cycle, student-centered inquiry, teacher-directed inquiry, alternative assessment, and the nature of science and the habits of mind (AAAS, 1993). Each topic was discussed in relationship to their experience. For example, one group discussed how their lesson demonstrated both constructivist teaching and constructivist learning. They systematically compared their experience to the recommendations made by Brooks and Brooks (1993), and they discussed how students may have constructed their knowledge according to Saunders (1992) and Driver, Asoko, Leach, Mortimer, and Scott (1994). Most groups were able to discuss their practice in terms of theory to the highest level of proficiency.

The final topic was something of each group's choice. The only restriction about the topic was that it must add to the student's understanding of the process of science teaching. Each group did present something that was salient to them. One group spoke about students' comments in accelerated and regular science classes. They specifically found, after they coded student comments, that students in accelerated classes were less likely to rely upon their teacher for direction and verification of their learning (teacher-independent), while students in regular classes were more likely to continually confer with the teacher about their progress (teacher-dependent). They went on to make implications for teaching all students in science. Other groups discussed locating important information on the internet, the use of video as a motivational tool, and laboratory safety in the public schools. Each group, in addition to creating meaningful discourse about being a teacher in science, achieved the highest level of proficiency.

Benefits and Detriments of the use of Rubrics

After utilizing rubrics in my Secondary Science Methods class, I have experienced certain benefits and detriments that are associated with their use. The benefits include reflective practice among my students and myself, and students utilizing rubrics in their own classes. The detriments are related to issues of time and the clarity of written criteria within a rubric. My conclusions are drawn from in-class observations of my students, course evaluations completed by my students, and various formal and informal comments made by my students.

I have found that rubrics, when incorporated into my instruction, can benefit my classes in two general ways. First, rubrics are a tool that can be used to encourage reflective practice. Schön(1983) and Baird et al. (1991) emphasize the importance of reflection in developing professional knowledge. The development of my own professional knowledge, through reflection, occurred as I constructed and utilized rubrics in Secondary Science Methods class. For example, in order to create a rubric for an assignment in science methods, I had to clarify the goals of the class and/or the goals within each lesson. I was forced to ask what was important about the lesson, how the level of understanding would be displayed by the students, and how my instruction would support the instructional goals specified in the rubric. In creating the rubric I was forced to reflect upon how I currently taught, how I achieved my goals, and how I would have to teach in order to support my goals. As I monitored each student's performance with the selected rubric, I was forced to examine how my practice was appropriate for my students. Each rubric that I utilized helped me to understand my enactment of practice and how my practice was understood by my students.

In addition to the personal reflection that I encountered, my students had several opportunities to reflect upon their practice with either the rubrics that I presented or the rubrics that they created. As students followed my rubrics, they were often asked to understand their practice and to connect theory to practice. In order to create a rubric, students had to work together to articulate the important components of the assignments. The discourse in the groups allowed students to challenge and redefine their ideas about (to list a few) assessment in the science classroom, the nature of science during investigations, and the importance of content knowledge. In either case, students had opportunities to examine their actions as they taught science, their beliefs about science teaching, and they had the opportunity to construct their knowledge about teaching science.

A final benefit that I have noticed is the use of rubrics in my students' own classrooms. Over three quarters of my students who experienced rubrics in Secondary Science Methods, now use rubrics in their own classes. Several of my former students have remarked that rubrics allow them to clarify their expectations to students, assist their students in thinking about the process of science, and encourage their student to go beyond a superficial level of thinking that can be found in many classroom investigations. While several of my former students use rubrics to clarify grading exceptions, one former student continues to assure me that her on-going goal is to have her students discuss what it takes to be an A, B, C, or D student in her class.

While it may seem that rubrics are a plausible tool to accompany practice, they are detriments associated with their use. The detriments tend to be related to time and the actual development of the criteria within the rubric. In regards to time, rubrics take time to create and use, from either the perspective of the instructor or the students. Time is needed to create a rubric and time is needed in order examine a task, performance, or artifact with a rubric. In addition, as rubrics are commonly prepared and presented, students begin to expect them. During one class I presented an assignment, but did not have the accompanying rubric. After class, several students asked when my rubric would be prepared and if it would be available by the next day. Thus more of my time was required to craft an appropriate rubric. And when is time is allocated, rubrics may not be valid indicators of performances. Depending upon the depth of articulation of the criteria within the rubric and depending upon who constructed the rubric, the validity of rubric may be compromised. Reliability is less likely to be affected, as all students are evaluated by the same rubric and the same assessor(s). Shaka and Bitner (1996) concluded that it was possible to obtain reliable scores, with training, between raters using the same rubric.

Conclusion

Rubrics, like concept maps and portfolios, are another tool for teacher educators to utilize in their classes. In addition to "clarifying expectations to students (ASCD, 1994)," rubrics can be templates that encourage reflective thought among students and instructors. For students, the process of creating rubrics can result in meaningful discussions about assessment, instructional goals, learning, and curriculum. As students utilize rubrics, they are provided with an opportunity to assess their own learning, and understand what they know about science education. Instructors who develop rubrics for their classes, constantly re-evaluate their instructional goals, and though student use are provided with an understanding of the effectiveness of their instruction and curriculum. The current use of rubrics among science teachers and science teacher educators will certainly provide additional information about their potential in the classroom.

There are no prescribed procedures for developing rubrics in science education courses, as rubrics are constructs that are dependent upon their purpose and their audience. It would be naive to suggest that rubrics developed within one class would be applicable to another class. Yet examining rubrics from other science education courses is an important part of initiating the development of rubrics in a class. Rubrics from other courses reveal the diversity in how purpose is defined and how the needs of different audiences are met.

Once a rubric is developed for a class, it becomes a tool that assists an instructor in enacting instruction and crafting curriculum. Rubrics provide information about students, and they provide science teacher educators with another view of their students and a view of themselves. Rubrics that are used without acknowledging the critical role of the instructor, have the potential to misled and limit their own and their students' growth. Ultimately, science teacher educators instruct, while rubrics clarify expectations.

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Figure 1

A	• Always prepared and attends class. • Participates constructively in class. • Exhibits preparedness and punctuality in class and work. • Student works well with others and is a team player. • Challenges his/her thoughts about science education (demonstrates initiative and improvement) and science. • Seeks to understand and acknowledge others' thoughts. • Demonstrates exceptional pedagogical content knowledge. • Often reaches full potential if sufficiently challenged. • Class assignments have an extra something about them. • Demonstrates the ability to integrate new knowledge into her/his work.
B	• Usually prepared and attends class. • Demonstrates excellent pedagogical content knowledge. • Challenges thought most of the time. • Participates in all class assignments, occasionally adds something extra. • Participates constructively in class, works well with others, team player. • Demonstrates initiative and improvement. • Seeks to understand and acknowledge others' thoughts. • Stretches to reach full potential.
C	• Sometimes prepared and attends class. • Average pedagogical content knowledge. • Occasionally or only challenges thought when encouraged to by others • Assignments reflect average work. • Not an active participant in class. • Works with others. • Most of the time prepared for class.
D	• Rarely prepared or attends class. • Does not participate constructively in class • Assignments are late, incomplete, or not turned in at all. • Low level of pedagogical content knowledge. • No challenge of thought • Does not strive to reach potential

Figure 2

Topic	4	3	2	1
Logistics	All parts are present: analysis of first and second lesson present; video of parts/all of the lesson; lesson plans and dates submitted; presentation lasts ten to fifteen minutes.	Most parts are present.	Some parts are present.	A few parts are present.
Presentation	The presentation lasts ten to fifteen minutes; lessons, learning experiences, and personal reflections are shared; and the presentation is preplanned, concise, and informative.	The presentation contains a majority of the previously stated elements.	The presentation contains several of the previously stated elements.	The presentation contains a few of the previously stated elements.
Reflection	Discussion goes beyond superficial treatment; presenters try to understand how and why, as well as present obvious findings; depth of thought is obvious. Reflection is relevant to science education.	The discussion addresses the obvious issues and tackles a few of the deeper issues. Depth of thought is somewhat apparent - there is room for more discussion. Reflection is relevant to science education.	The discussion addresses some of the obvious issues and attempts to understand deeper issues. Depth of thought is present, and more could be discussed. Reflection may or may not be relevant to science education.	The discussion addresses some superficial issues, and lacks in-depth analysis. There are clear holes in the reflection. Reflection may or may not connect to science education.
Connections	Both the written material and the presentation connect theory to practice (discussion is supported by readings and class topics).	There are some connections made, and some obvious connections that need to be made.	There are some connections made, some connections that need to be made, and inaccurate connections.	The written material and presentation could have a greater connection of theory and practice.
Something Extra	There is clearly something extra in the analysis and presentation. The teacher does not have to struggle to identify this item. The item is unique and adds to the student's understanding of the process of science teaching.	There is something extra in the assignment. The extra item makes some contribution to the student's understanding of the process of science teaching.	There is something extra in the assignment that makes little contribution to the student's understanding of the process of science teaching.	There appears to be something extra in the assignment, but the teacher is unsure of what it is and/or it doesn't contribute to the student's understanding of the process of science teaching.

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