Characteristics of Science and Mathematics Departments producing Outstanding Educational Outcomes in Public Secondary Schools

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Abstract

An Exceptional Schooling Outcomes Project (ÆSOP) was designed to analyse ‘schooling’ processes and the characteristics of subject-departments that generated outstanding educational outcomes for students in public schools in New South Wales, Australia. Selection included ‘value-added’ data around student achievement for Years 5-10, results from state-wide examinations in Years 10 and 12, along with endorsement from local educational authorities. Fifteen schools were visited for one week with data collected from interviews with Principals, Deputy Principals, teachers, students and parents; lesson observations; and documentary artifacts. Using a grounded theory approach, five major elements emerged across science and mathematics departments: Climate, Teacher-student relationships, Teaching strategies, Teacher professionalism, and Resources. The final element, School contextual factors encapsulated the supporting structures evident within the school environment.

Background

An extensive body of research exists that highlights the importance of the roles played by the school Principal at one end of the spectrum and the individual classroom teacher at the other, in advancing the quality of students’ educational outcomes as they proceed through school (Elmore, 2008; Hattie, 2003; Patchen, 2004; Sammons et al., 1997). However, there is comparatively little research on the significance of the roles played by subject departments and other groupings of teachers.

How to improve outcomes in schools is an enduring concern in most national and international education systems (Scheerens et al., 2003). In many parts of the English-speaking world, reliance has been placed upon school ‘inspection’ systems and various quality assurance mechanisms based on deficit-modeling: identifying weaknesses and failings and following this up with programs of remediation and/or processes to improve results. Measures, such as school-average performance or the use of ‘league tables’ that rank schools, have drawn extensive criticisms in the media, and from academics and parents. The results are not only seen as potentially destructive as measures of school performance, but they often provide no mechanism for schools to improve their performance. As an alternative, an Exceptional Schooling Outcomes Project (ÆSOP) was designed to investigate the principles, processes and practices in a sample of public schools in New South Wales (NSW), Australia producing outstanding educational outcomes for students in Years 7-10 (i.e., aged 12-15 years). It represented a collaborative study involving university academics and staff from the Department of Education and Training (DET). The research focus
was on ‘teams’ of teachers in an attempt to identify ways in which groups of teachers create richer and more effective learning environments for their students resulting in higher student achievement. While the broader study included a number of subject areas (e.g., English, physical education, history), science and mathematics departments are the focus of this paper.

**Research Context, Design and Methods**

The NSW DET public schooling system is the largest in Australia. It oversees the collection of quantitative data for all students attending public schools based on a series of standardised literacy and numeracy tests (in primary school) and Year 10 reference tests. These data are provided to Principals annually and used by the school staff to reflect upon their successes and failures in meeting student needs. In terms of the present study, access to this longitudinal data provided an evidence-based and defensible mechanism for identifying schools achieving outstanding educational outcomes for students in junior secondary science (i.e., Years 7-10) for inclusion in the study.

Within the NSW public education system, secondary schools are structured around Key Learning Areas (KLAs) or discipline-related areas. Head Teachers provide leadership and a mentoring role to the staff within a specific discipline (i.e., science or mathematics) so form a crucial middle management position within the school. The discipline groupings of teachers are referred to as either departments or faculties (i.e., science department or faculty).

**Selection of Sites in Schools**

The basic source was value-added data (Thomas et al., 1997) collected for all students attending DET public schools in NSW. This was derived using standardised assessments in Year 5 (basic skills tests), Year 7 (literacy and numeracy tests), along with tests completed for the School Certificate in Year 10. To meet the first level of selection a school had to demonstrate that low, middle and high achieving students scored above the NSW mean for the value-added data. Importantly, this success had to be evident over four-year period. Once a pool of potential science and mathematics sites within schools was identified, the second level of selection included qualitative data with nominations sought from key educational groups across NSW including DET senior staff in each jurisdiction, parental groups, and other professional organisations. Schools were chosen to ensure a cross-section of socio-economic status and geographical locations. Visits were made to seven schools for science and eight schools for mathematics. Finally, The Adelaide Declaration on National Goals for Schooling in the Twenty-first Century (MCEETYA, 1999) was used to ensure that each of the sites visited provided equitable learning for all students.

**Study Design**

In overview, the first year was spent accumulating and analysing the quantitative and qualitative data on the 458 secondary and central schools in NSW, and the preparation, administration and analysis of a survey to all these schools. Pilot studies were also undertaken to familiarise the project team with the procedures to be employed in the main study, and to refine the research instruments, data collection and analysis procedures.

The second year included intensive case studies research within the schools selected. Each study involved a research team consisting of a university researcher in a related subject (i.e., science or mathematics education), a university researcher with expertise in case study methodology, the local Chief Education Officer (CEO) for School Improvement from DET, and a head teacher (science or mathematics) from a nearby high school. The team spent up to five days in each school collecting evidence.

As a result of these findings, the final year focused on the analysis of results and development of a series of monographs. This stage involved frequent meetings of the research team.
Data Sources and Analysis Techniques

Within each school, the research team collected a range of data from semi-structured interviews with Principals, Deputy Principal(s), Head Teachers, subject teachers, school advisors, students (Years 7-11), and parents. Lesson observations using a specified protocol were undertaken with teachers who agreed to be involved. Additionally, documentary analyses were completed using school results, subject programs, assessment tasks, school and faculty policy documents, and any other documents deemed appropriate (e.g., media coverage). All interviews were taped and transcribed.

Results and Discussion

Analysis of the science and mathematics data identified five major elements in relation to departments encompassing a number of themes (Table 1). Explanations for 1 or 2 themes within the elements are provided in this section.

Climate

Collegiality

At the individual level, teachers were cognisant of issues their colleagues faced and were supportive of one another’s challenges and achievements. Teachers had established good working relationships with their peers and used their initiative to determine ways to help colleagues maintain a high-quality learning environment for their students.

The science faculty has a good concept of team. For any effective faculty there has to be a close collaboration between the members. It has to be a place where sharing is an everyday thing. Where support of colleagues is a matter of fact thing – it occurs naturally, without any pressure. Where those who are perhaps the weak links are encouraged and provided with material support and with confidence (School Principal).

Enculturation

Each team of teachers exhibited a clear sense of pride in the culture of success they helped create and this was disseminated to newly appointed teachers. New teachers who came to the schools spoke about encountering an “established departmental culture” with “an expectation to meet relatively high standards” of performance. The enculturation of new staff was implicit and/or explicit ensuring that members of these departments were able to advocate and share a common vision that encouraged a consistent staff approach.

The staff in mathematics are very willing to share their expertise. If you have got a problem, you ask someone. If you don’t know how to teach something you ask someone. You are never made to feel dumb. You are never made to feel in any way inadequate (New teacher).

Assessment as a catalyst for teacher cohesion

The departments had well-developed assessment regimes focused around monitoring students’ understandings in relation to their peers. Importantly, the development and marking of assessment tasks was used as a stimulus to discuss with colleagues aspects about teaching and ways in which assessment informs practice. These discussions helped to explore and better understand the major issues, what were important subsidiary ideas, and the nature of questions that would elicit greater student understanding in science and mathematics. For students, assessment served to provide a catalyst to assist them in developing and consolidating their understanding. It also enhanced their skills, expectations and preparation for examinations, and the establishment of regular patterns of study.
Table 1. Overview of elements and themes for science and mathematics faculties

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<th>ELEMENT</th>
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| Climate                  | Referred to the ‘atmosphere’ created by a shared vision and camaraderie that characterised the grouping of teachers | • Collegiality  
• Support for new and inexperienced staff  
• Enculturation of new staff (mentoring)  
• Catering for individual differences  
• Assessment a catalyst for teacher cohesion  
• Grouping practices for students  
• High degree of scholarship |
| Teacher-Student Relationships | Encapsulated the high value placed on developing positive, productive relationships | • Shared, high expectations  
• Positive impact on building self esteem and confidence  
• Mutual trust and respect  
• Community endorsement and links  
• Caring for students and their learning  
• Creating positive classroom environments |
| Pedagogy                 | Embodied the learning opportunities created by teachers within their classrooms | • Consistent, quality teaching  
• Ability to engage student interest and enjoyment  
• Structured, organised lessons  
• High ‘on-task’ time  
• Variety of tasks and activities  
• Solid classroom management |
| Teacher Professionalism  | Captured the degree of scholarship of the teaching team                      | • Interest, expertise and passion for science and mathematics  
• Shared goal setting  
• Reflecting on their teaching practices – “learned from experiences”  
• High expectation of all students  
• Engagement for formal and informal professional development |
| Resources                | Incorporated the different types of human and physical resources contributing to success | • Stable core of experienced and committed teachers  
• Qualified teachers (solid PCK)  
• High quality leadership  
• Communal teaching resources  
• Designated teaching and teacher spaces  
• Teaching programmes evident  
• Pool of experienced casual or relief teachers |

NB: bolded themes are discussed in this paper
Teacher-Student Relationships

*Shared, high expectations*

A lot has to do with the kids. The kids are on the whole studious, value an education, and they’re concerned about their progress and that makes a big difference ... The support you get from the families ... If they are away for a day and miss something then they worry about what they have missed. Not like other kids who say ‘hooray I have missed something’, they worry about it.

This quote is illustrative of how teachers and parents attributed reasons for the exceptional performances in the schools. A common theme associated with these observations was mutual respect among all parties. Teachers acknowledged that students and their parents were a central reason for the results obtained, whereas parents and students considered the teachers as being the key. An important feature was that all three stakeholders (teachers, students and parents) moved in the same direction. In these exceptional departments there had developed over time a culture of success and achievement for students of all ability levels.

Pedagogy

*Structured, organised lessons*

All teachers interviewed referred to their style as “fairly traditional” meaning it involved a “standard” approach to classroom instruction. While there were variations to the meaning of a standard approach there was a great deal of commonality across schools. In particular, there was a clear and consistent structure to lessons. This structure provided a sense of “security to students” in their learning. Nevertheless, within this structure, there was still variety in these lessons. For students, lessons were not dull, repetitive or boring.

An interesting observation made in relation to science was that even in schools with 40-minute lessons, science teachers were able to conduct investigations and/or laboratory activities with their students. It was clear that this was possible because teachers were able to ‘orchestrate’ the workings of the science classrooms because the students were able to function efficiently, safely and methodically.

*High ‘on-task’ time*

Time on-task was maximised by the teachers and students at the schools visited. Emphasis around ‘on-task’ time and a commitment to a cooperative and supportive environment were high on the teachers’ agendas. Classroom teachers made every effort to ensure that students were actively engaged in the learning process. Time-on-task was considered a vital factor in helping students achieve their academic potential.

Having explained these factors it was clear from the student forums that they were engaged and enjoyed science and mathematics lessons. Teachers outside the specific departments involved were able to corroborate this perception.

*From my own experience, students seem pretty happy in science. There are fewer problems brought to me by the science teachers than by any others. They seem to talk to the kids rather than passing them onto us whereas you see with other teachers they just can’t work it through. I have also noticed fewer complaints from students about science staff than others (Year 10 year adviser).*

Teacher Professionalism

*Shared goal setting*

As a collective, the teachers in a department shared a clear vision about what they were trying to achieve and were keen to assess their effectiveness in achieving these outcomes. This thoughtful,
reflective approach was evident in the teaching and also in the way department policies were articulated to staff, students and parents.

**Reflecting on their teaching practices**

Teachers demonstrated very thoughtful and reflective approaches to their teaching. As individuals they reflected on their teaching practice and, as a group, they engaged in frequent and rigorous professional discussion about teaching strategies.

*I have never been in a faculty before where there has been so much discussion about mathematics at recess and lunchtime. They constantly say things like, ‘how do you do this?’, ‘where are you up to?’, ‘what are you going to do next?’ or ‘don’t forget to teach (such and such)’* (Mathematics teacher).

**Resources**

**Stable core of experienced and committed staff**

Teachers in these departments had many years of successful teaching experience, often in several schools. Subsequently, they brought a wealth of different experiences to their current positions. Importantly, a large proportion of the science and mathematics teachers interviewed in this project had been in the study schools for eight years or more.

**Qualified teachers**

The science and mathematics teachers in these schools had a high degree of discipline knowledge with the majority holding degrees in their specific subject areas (e.g., Bachelors of Science degrees comprising 3-years of university study).

As a consequence of these characteristics, the science and mathematics departments included in the AESOP study could best be described as *communities of scholars* with deep knowledge of the subject and a special pride in teaching clearly evident. Their work was well recognised by staff outside the department who were aware that the science and mathematics teachers always exhibited a high degree of professionalism.

**Broader School Factors**

In considering the findings for science and mathematics departments, it is important to highlight the *School contextual factors* that underpinned the success of these departments within their schools. These included: school culture and climate, leadership by the executive, across-school policies and programs, and wider community endorsement. The significance of these factors is that they appeared to provide a critical foundation upon which the teams of science and mathematics teachers were able to *build* their success in relation to student learning within the schools.

**Educational Importance of the Study**

It is clear from these findings that these outstanding science and mathematics departments had evolved over time to develop a strong academic and educational culture in their schools. The teachers in these schools realised there was no opportunity for “resting on their laurels” with continued effort required to maintain these high standards.

When considered independently, a number of the findings presented here support previous research undertaken in relation to student achievement and teacher-school effectiveness. However, the significance of results from this study is the important contribution played by the science and mathematics departments in terms of creating a *community of practice*. It was the way in which each team of teachers functioned holistically by working towards a common goal, sharing resources, engaging collaboratively and professionally with one another that ultimately made the difference. While the school provided a potential springboard for success by departments, it must
be remembered that not all teams of teachers within the schools visited for the ÆSOP study were achieving similar levels of success with the same group of students.

**Please note:**
This paper provides a summary of results from the study for Science and Mathematics departments. A detailed report is available in the following two books:


**References**


