the given procedure, of choosing a sheet "near the middle of the book," although this does represent a misconception some students may have whereby they confuse the middle of the book with some notion of averaging.) To see this, and to determine how many sheets should be used, consider the following.

The uncertainty in a single micrometer reading is typically ± 0.01 mm, and the aim is to adopt a procedure that minimizes (and ideally makes negligible) the percentage uncertainty in the final result. Whereas ± 0.01 mm in 0.08 mm (a typical single-sheet thickness) represents $\pm 12\%$ uncertainty, ± 0.01 mm in 8.05 mm, say (a typical 100-sheet thickness) represents only $\pm 0.1\%$ uncertainty, which is negligible. In the latter case, the thickness of a single sheet would be expressed as $8.05 \times 10^{-2} \pm 0.1\%$ mm. If we were to consider a percentage uncertainty of $< 0.25\%$, say, to be negligible, then this type of analysis leads us to conclude that we would need to use 50 or more sheets.

For comparison, students could be asked to similarly determine the thickness of a single sheet using a ruler. Typically, 100 pages might measure 8.7 ± 0.5 mm = $8.7 \pm 6\%$ mm, giving a single-page result of $8.7 \times 10^{-2} \pm 6\%$ mm; 60 times less precise than the corresponding micrometer determination.

Reference

Eastwell, P. H. (2006). Levels of enquiry. *The Science Education Review*, *5*, 61-63.

The Future of Student Grouping Systems in Science 14-16

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Abstract

Ability grouping is a contentious issue in high school science education, and one that divides teachers, parents, and policymakers alike. However, it may be that current grouping systems are founded on ideas that are failing to provide for the best interests of students at any ability level. This article aims to review current practice and its effects on student and teacher outcomes, and suggest a new direction for student grouping polices based on the ideal of "science for all" through curriculum reform and choice-based modular course systems. The article is based largely on the British education system.

Introduction

Recent research into the effects of setting (subject-specific ability grouping) and mixed-ability grouping in British schools has yielded mixed results and painted a confusing picture of how these influence teaching and learning in science. One thing has become certain, though; setting is associated with both high- and low-ability student achievement and self-concept in some way and to some degree. In one study, it was even suggested that the set a student is placed in has more bearing on the student's eventual achievement than the school being attended (Wiliam & Bartholomew, 2004).

Setting by ability has been suggested by the Office for Standards in Education (Ofsted, 1998) as a method for improving performance in schools, and the Department for Education and Employment

(DfEE, 1997) state that setting should be the norm in secondary schools in England. Benn and Chitty (1996) report that 40% of secondary comprehensive schools use some form of setting in Year 9, and that it is virtually certain to be taking place in one or more subjects in Year 10 and above.

Setting has been a feature of the British education system for at least 100 years, and in its historical incantation was based upon theories, such as those of Spearman and Pearson, relating to the fixed, immutable, and genetically-determined nature of intelligence. These theories relate to the transmission model of learning, whereby some minds are more receptive to knowledge than others and will therefore achieve more highly in the future, and vice versa. It also reflected, to some degree, stratifications that existed (and indeed still do exist) in society. However, more modern theories typically categorise different types of intelligence, such as linguistic, logico-mathematical, spatial, musical, and so forth (Gardner, 1993, 1999).

Systems of pupil placement, whether they be mixed or set by ability, must be in accordance with, and indeed ought in some measure to support, the espoused goals of good educational practice. These might come under the banner of achieving “science for all” and fulfil the high ideals of inclusivity via differentiation, authenticity, constructivism, agentive learning, dialogic discourse, social interaction, flexibility of approach, effort based assessment, motivation, equality, diversity, and valuing each other.

Review of Research

Effects of mixed-ability grouping on teaching and learning. Pupils' abilities vary across, and indeed within, different subjects. *Launch Pad 3* (2000) concludes that therefore “it is inadvisable to group students identically across the curriculum . . . [and] grouping identically within one subject may have limitations too” (p. 2).

Although it is clear from some research that mixed-ability grouping benefits the low-ability students academically, some of the same evidence points to the fact that high-ability students do better, and take science further, when placed in high-ability sets (Boaler, Wiliam, & Brown, 2001; Farrar, Evans, & Kirk, 2003; Ireson, Hallam, & Hurley, 2001). Would mixed-ability grouping reduce the number of future scientists and hence be contrary to the goal of science for all? Is it possible to justify holding back one group of learners in order to benefit another? Doctor Linda Silverman, of the Gifted Development Centre in Colorado, USA thinks not. In her treatise on the importance of selective education for high-ability learners (Silverman, n.d.), she states that it is undemocratic not to provide for the needs of high-ability learners and that “it is misguided to believe that holding back the brightest students magically helps the slowest ones; bringing the top down does not magically bring the bottom up” (p. 4).

There is little evidence to suggest that mixed-ability groups really do receive differentiated work, and in fact some research suggests that both high- and low- ability students are not being taught at appropriate levels in mixed-ability groups at secondary school (Department for Education and Science [DES], 1992). Successful mixed-ability teaching requires skilled teachers who are flexible, employ a variety of teaching methods, approaches, and resources, and have good formal and informal relationships with students. Current opinion is turning against mixed-ability grouping, as reported by the BBC news service (BBC, 2001). A survey of 1500 teachers revealed disruptive behaviour and a more taxing teaching environment resulted from mixed-ability classes. Science is particularly unsuitable for mixed-ability grouping as all students must have mastered the basics of one concept before they can move on.

On the other hand, Farrar et al. (2003) have shown that low-ability students sometimes feel that they benefit from the presence of their high-ability counterparts, voicing such sentiments as "I worked with smart people. When I didn't understand something they nicely explained it to me" (p. 54). Vygotskyian theories see learning as taking place through interaction with others, and it would be a shame to separate these students and hence lose this discourse. In addition, the high-ability learners could be developing other facets of their intelligence and understanding by interacting with low-ability learners in this way. However, such outcomes are seldom, if ever, measured in attainment tests, which rely more on coverage of curriculum content; and this almost certainly proceeds more slowly in mixed-ability groups than in top sets.

Setting systems. Ireson, Clark, and Hallam (2002) used questionnaires to determine setting considerations used by schools. The most common responses were:

- Internal tests and examinations
- End of year tests
- The Cognitive Abilities Test
- Teacher opinion or "gut feeling"
- Student behaviour and motivation
- Social factors (e.g., avoiding problematic student combinations)
- Gender (balancing/single sex setting)
- The provision of special educational needs (SEN)

Ethnic group was never mentioned, despite bottom sets continuing to contain disproportionately high numbers of ethnic minorities, and particularly afro-caribbeans (Ireson, Clark, & Hallam, 2002). The same study found disproportionately high numbers of students of low socio-economic status, boys, and children born in the summer (youngest in the age group) in the bottom sets. Interestingly, the students' own choice never appeared to influence the set they were allocated to in the UK.

Movement between ability groups is seen as crucial, by Ofsted (1998), to the successful operation of structured grouping systems and would certainly be necessary if the principles of equality, motivation, recognition of effort, and flexibility were to be satisfied. Ireson, Clark, and Hallam (2002) report a great deal of variability between schools as to how students are moved between sets. Reasons range considerably, but all are related to those used for set allocation in the first place. In reality, however, there is little movement between sets in the UK, often due to gaps between the work undertaken by the different sets. This is a problem particularly when lower sets study the foundation tier syllabus at Year 10 and students are unable to move up in Year 11 to sets where the higher syllabus has been studied (Gillborn & Youdell, 2000). There are also often problems of higher sets becoming oversubscribed and thus requiring that students move down in order to make room for those coming up (Ireson, Hallam, & Plewis, 2001). Someone must always be at the bottom of the top set, and this individual may feel negative self-concept effects as a result of being moved down.

Effects of setting on teaching and learning. Several questionnaire-based studies have shown that a majority of students aged 14-16 years prefer setting to mixed-ability grouping (Hallam & Deathe, 2002; Ireson et al., 1999) and therefore there must be something about setting that appeals to them. Research by Farrar et al. (2003) involving high school Biology students in the USA suggested that, in practical work, high-ability students preferred to work with other high-ability students. This seemed to be because, while working with lower-ability students, they ended up doing the “lion’s share” of the work.

Hallam and Deathe (2002) conducted a study into how grouping affected students’ self-esteem and attitude, and found that:

- Students in bottom sets experience negative effects on aspects of their self-concepts, such as self-esteem and sense of self-worth.
- The longer a student remains in a bottom set, the greater the negative effects on all aspects of their self-concept.
- Top-set students may also experience negative self-concept effects as a result of peer-pressure factors.

Further work by Hallam and Ireson (2003) showed teachers believed that:

- Setting prevents brighter children being inhibited by negative peer pressure (presumably from less able classmates).
- Being in a low set leads students to “give up.”
- Setting pupils stigmatises them in some way.

Boaler et al. (2001) suggest that many of these negative effects stem from the ways that teachers behave towards the students in the sets themselves, and Hallam and Ireson (2003) concur, suggesting that teachers’ attitudes towards teaching low-ability groups may have contributed to the alienation of those pupils. In other words, it is not a case of simply being in a certain set, it is how you are treated once you are there. Boaler et al. describe factors which could be responsible for the erosion of student self-concept, such as excess pressure and pace, demotivating language use by teachers, and threats of set demotion.

Several studies have shown that setting tends to increase the achievement of high-ability students at the expense of low-ability learners (who perform better in mixed-ability sets), thus polarising the achievement of the year group (Boaler et al., 2001, Farrar et al., 2003). Ireson, Hallam, and Hurley (2001) researched 45 mixed secondary comprehensive schools in England and came up with some interesting data. They found that schools that set by ability encouraged a greater number of students to take science at a higher level, with 36% of students going on to take a science A-level compared to 25% at non-set schools. However, 17% of students from set schools were totally disaffected with science, stating that they never wanted to do science again after age 16, compared with 14% in schools with mixed-ability classes. This may be further evidence of polarisation of attainment and attitude. From a sociological perspective, in a world where the rich are getting richer and the poor getting poorer, perhaps this outcome of setting is merely echoing one of the more disappointing aspects of our society today?

Setting procedures should enable science teachers to lead their students to develop a deeper understanding of the subject via social and cultural constructivism, through dialogic discourse that promotes cognitive conflict in situations where the material is authentic and relevant and the learners are motivated and empowered. Ireson et al. (1999) canvassed the opinions of 1601 teachers as to their opinions of setting and discovered the following:

- Setting is beneficial for high-ability learners.
- Setting makes teaching easier.
- Low-ability classes suffer from more discipline problems, as do mixed ability groups.

- Low-ability classes tend to access less of the curriculum, have more repetition, and have less homework, independent work, responsibility, and discussion and analysis than higher- or mixed-ability groups.

Some of these outcomes are consistent with the aims of science education, but these seem to be limited to the high-ability groups. If the teachers are right, then the low-ability groups are not being given equal access to quality learning experiences.

A very interesting and candid survey, of high school history teachers in Zimbabwe, threw up some startling results (Chisaka, 2002).

- "Ability grouping is meant to avoid the pupils who are above average being disturbed by pupils who have discipline problems. It is also an attempt to motivate teachers in the sense that, when they go to that class (high ability), they have the hope that that particular class is capable of making it every day" (p. 28).
- "Teachers don't prepare much for the lower streams--they don't research much . . . but with the upper streams they really work" (p. 28).
- "Teachers give more work to A classes than to B classes" (p. 28).
- "These top classes are the classes on which we bank when it comes to (final) results" (p. 29).
- "Because of unavailability of resources, teaching the lower streams becomes a nightmare" (p. 29).
- "The teacher is negatively motivated when he is going to a dull class" (p. 29).

Lacey (1970) reported that, in a selective school, the top set received better resources and more teacher attention, to the detriment of the lower groups. It may, or may not, be that this is still the case today. Teachers generally prefer high-ability groups, feeling more efficacious and interacting more frequently and positively than with low-ability groups (Hallam & Ireson, 2003). The same authors describe teachers of low-ability sets becoming gradually demoralised in an atmosphere of negative attitudes towards school and poor behaviour.

Boaler et al. (2001) present some disturbing evidence of poor-quality teaching methods taking place in bottom math sets in the UK. The article reveals unprofessional, unkind, and demoralising behaviour on the part of the teachers, with remarks such as "you're the bottom group, you're not going to learn anything" (p. 638). Other such statements in the report reveal low expectations, a lack of differentiation in low-ability groups, more tedious teaching methods, such as copying, being employed, and less investigation; in other words, plain bad teaching practice.

Studies suggest that bottom sets are typically assigned to younger, less-qualified, and less-experienced teachers (Boaler et al., 2001; Wiliam & Bartholomew, 2004,). This is contrary to the best interests of the students, as there is also evidence that bottom sets experience the most benefit from high-quality instruction (Black & William, 1998). Students in low sets for maths in the UK have remarked that "our group keeps changing teachers . . . [because] they don't think they have to bother with us . . . . They get say a teacher who knows nothing about maths . . . a PE teacher or something . . . They think they can send anyone down to us" (Boaler et al., p.637).

There are no government guidelines as to how teachers should be assigned to sets, and this seems to be carried out, for the most part, on a very ad hoc and unregulated basis. It is unsurprising that teachers do not like being given bottom sets, as current indices of educational success often focus on the production of grades that lower sets seldom achieve, often because they study the foundation tier. Young, inexperienced, or under-qualified staff may often enter bottom-set science lessons ill-prepared, demotivated, anticipating discipline problems, and setting low expectations. They then teach dumbed-down curriculum material (most of which bears no relevance to the students' lives), using inadequate resources in an uninspiring fashion, to students who consider themselves doomed to failure. Discipline problems that have been reported may even be in part caused by the inexperience, lack of motivation, or lack of training of the teachers in those sets.

Summary of Findings

Mixed groups are unpopular with staff and pupils and are unsuitable for science as a subject, although they seem ethical on the surface and are easily achieved, requiring little effort on the part of middle management (which is perhaps one reason why they are so commonly used).They also do not allow all students to reach their full potential and reduce the number of students who take science beyond age 16.

Setting systems may be based on inappropriate measures, such as teacher guesswork and behavioural issues, and bottom sets often contain disproportionately high numbers of poor, male, summer-born students and those from ethnic groups. High numbers of students are placed in the wrong sets and are then unable to move due to curriculum and organisational factors. Labels associated with both high and low sets result in the stigmatisation of students, and self-concept is damaged. Student motivation in bottom sets falls, and a sense of failure and disaffection develops as attainment is polarised. High-ability students achieve better grades than they would have in mixed-ability sets and take science further, but it may be at some cost to their lower-ability schoolmates. Teachers prefer the high groups and teaching quality falls in lower sets, which are often taught by ill-prepared and inexperienced staff.

What often results from these systems, particularly in lower sets, is a culture of failure, refusal to engage, symbolic violence, and negative attitudes towards science from a large number of students who have been failed by the system and then fail their examinations. Issues of gender, ethnicity, and class bias arise and the values of society are challenged. Young and inexperienced teachers are demotivated and high-ability students fail to reach their full academic potential.

Option-Based Setting Systems: A New Perspective?

Some features that might characterise an improved setting system are:

- Flexibility of movement between sets and regular pupil review.
- Placing more emphasis on effort than on attainment when assigning sets.
- A modular curriculum that allows students to select what they study, giving them greater responsibility and ownership.
- Differentiation within all groups to cater for differences in ability (Ireson et al., 1999).

I would add that a setting system for students aged 14-16 years in science would:

- Take modern educational perspectives on multiple forms of intelligence into account and avoid grouping using inappropriate measures such as behaviour.
- Assign teachers based only on what would be best for the learners in that group.
- Cater to motivated future scientists, and future consumers of science, separately within a choice-based modular context.
- Allow mixed-ability groups to form and avoid "bottom sets," while allowing high-ability learners to achieve their potential in science separately.

- Take into account issues of gender and race to avoid sets where racial groups and/or boys predominate.

A case study: Sandringham School in Hertfordshire. Sandringham School has attempted to increase high school student motivation by introducing a system that allows them to pursue their studies via modules, which students choose on the basis that they find them interesting or relevant. This approach has been very popular with both parents and pupils, who enjoy the greater autonomy and ownership that it gives them over their learning. The school's Ofsted report (*Inspection Report: Sandringham School*, 1999) was highly complimentary of their approach, commenting that it helped to "develop a feeling of self worth and success" (p. 29). It also comments on the degree of flexibility in the curriculum being far higher than normal and consider this to have been in part responsible for improving GCSE examination results at the school. The report also finds the children motivated, well-behaved, and responsive in science lessons. Both high- and low-ability students are further catered for in out-of-class "high fliers" and "catch-up" sessions, and ability grouping is not used.

Sandringham is a non-selective, comprehensive school and was formed as a result of the amalgamation of two failing schools. Many such initiatives fail, but Sandringham went on to be hailed by Ofsted as the third best-performing comprehensive school in the country in 1997 and continues to do very well in both pastoral and academic spheres. The Headmaster attributes the school's success to three factors, the first of which is an exciting and motivating curriculum, especially at Key Stage 4 (ages 14-16 years), taught by highly-qualified and dynamic teachers. This case study shows that a student choice-based, non-ability grouping modular approach could be successful in raising standards in science by increasing inclusivity and access to science for all.

References

BBC. (2001). *Doubts over mixed ability classes*. Retrieved October 4, 2005, from http://news.bbc.co.uk/2/hi/uk_news/education/1528573.stm .

Benn, C., & Chitty, C. (1996). *Thirty years on: Is comprehensive education alive and well or struggling to survive?* London: David Fulton Publishers.

Black, P. J., & William, D. (1998). Assessment and classroom learning. *Assessment in Education*, *5*, 7-73.

Boaler, J., Wiliam, D., & Brown, M. (2001). Students' experiences of ability grouping: Disaffection, polarization and the construction of failure. *British Educational Research Journal*, *27*, 631-648.

Chisaka, B. C. (2002). Ability grouping in Zimbabwe secondary schools: A qualitative analysis of perceptions of learners in low ability classes. E*valuation and Research in Education*, *16*(1), 19-33.

Department for Education and Employment (DfEE). (1997). *Excellence in schools* (Cm.3681). London: HMSO.

Department for Education and Science (DES). (1992). *The education of very able children in maintained schools: A review by HMI*. London: HMSO.

Farrar, E., Evans, R., & Kirk, M. (2003, December). The effect of ability grouping on student attitudes and achievement in science labs. In L. P. McCoy (Ed.), *Studies in Teaching: 2003 Research Digest* (pp. 51-55). Research projects presented at Annual Research Forum, Wake Forest University, Winston-Salem, NC. Retrieved October 15, 2005, from http://www.wfu.edu/education/gradtea/forum03/f03.pdf .

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gardner, H. (1999). Are there additional intelligences? The case for naturalist, spiritual and existential intelligences. In J. Kane (Ed.), *Education, information and transformation* (pp. 111-131). Englewood Cliffs, NJ: Prentice Hall.

Gillborn, D., & Youdell, D. (2000). *Rationing education: Policy, practice, reform and equity*. Buckingham: Open University Press.

Hallam, S., & Deathe, K. (2002). Ability grouping: Year group differences in self-concept and attitudes of secondary pupils. *Westminster Studies in Education*, *25*(1), 717.

Hallam, S., & Ireson, J. (2003). Secondary school teachers' attitudes towards and beliefs about ability grouping. *British Journal of Educational Psychology*, *73*, 343-356.

Inspection report: Sandringham School. (1999). Retrieved September 23, 1995, from http://www.sandringham.herts.sch.uk/about/pdfs/ofsted99.pdf .

Ireson, J., Clark, H., & Hallam, S. (2002). Constructing ability groups in the secondary school: Issues in practice. *School Leadership and Management*, *22*, 163-176.
Ireson, J., Hallam, S., Hack, S., Clark, H., & Plewis, I. (2002). Ability grouping in English, mathematics and science: effects on pupil attainment. *Journal of Educational Research and Evaluation*, *8*(3), 299-318.
Ireson, J., Hallam, S., & Hurley, C. (2001). *Ability grouping in the secondary school: Effects at Key Stage 4.* London: University of London, Institute of Education. Retrieved August 24, 2005, from http://k1.ioe.ac.uk/schools/phd/docs/Nuffield_report.pdf .
Ireson, J., Hallam, S., & Plewis, I. (2001). Ability grouping in secondary schools: Effects on pupils' self–concepts. *British Journal of Educational Psychology*, *71*, 315-26.
Ireson, J., Hallam, S., Mortimore, P., Hack, S., Clark, H., & Plewis, I. (1999). *Ability grouping in schools: Practices and consequences*. London: University of London, Institute of Education. Retrieved August 24, 2005, from http://k1.ioe.ac.uk/schools/phd/docs/ESRC_report.pdf .
Lacey, C. (1970). *Hightown Grammar: The school as a social system*. Manchester: Manchester University Press.
Launch Pad 3: Pupil Grouping. (2000). Oxford: Oxford Brookes University, Westminster Institute of Education. Retrieved August 19, 2005, from http://www.brookes.ac.uk/schools/education/rescon/cpdgifted/docs/secondarylaunchpads/3grouping.pdf .
Office for Standards in Education (Ofsted). (1998). *Setting in primary schools: A report from the Office of her Majesty's Chief Inspector of Schools*. London: Office for Standards in Education.
Silverman, L. (n.d.). *Gifted education: An endangered species*. Denver: The Institute for the Study of Advanced Development. Retrieved September 2, 2006, from http://www.gifteddevelopment.com/PDF_files/g20.pdf .
Wiliam, D., & Bartholomew, H. (2004). It's not which school but which set you're in that matters: The influence of ability grouping practices on student progress in mathematics. *British Educational Research Journal*, *30*(2), 279-293.

Ideas in Brief

Summaries of ideas from key articles in reviewed publications

The Google Calculator

Google (2006) offers a new tool that numerically evaluates equations while also tending to units and mathematical and physical constants. To get a feel for how the calculator works, google (i.e., type in the Google search bar and press the *Google Search* button) "2*3=" (but without the quotation marks) to find that the answer "6" appears. Then click on *More About Calculator*, which appears under the answer, to learn more about formatting equations for Google.

Google "G" to find the value for the gravitational constant appear. Google "G*mass of the sun*80 kg/(radius of the sun)^2 in pounds force" to determine that a person registering 80 kg (165 pounds) while standing on a bathroom scale on earth would need a scale capable of reading 4,934.55214 pounds on the sun. (Users need to adjust answers to the appropriate number of significant figures.) Further information may be found at *GoogleGuide: Calculator* (2006) and Ward (n.d.).

Ward (2006) believes that future students will leave unit conversions, unit checking, algebra, calculus, and looking up constants to computers, in the same way our generation has passed off arithmetic and the like. And, the sooner they begin, the better, as this will allow time to concentrate on the really important concepts. String theory, for example, could be introduced to high school students before they graduate.

References

Google. (2006). Retrieved October 24, 2006, from http://www.google.com.au/ .
GoogleGuide: Calculator. (2006). Retrieved October 24, 2006, from http://www.googleguide.com/calculator.html .