Intelligence – A Natural Debate

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***Abstract*— This paper argues that intelligence (the ability to complete tasks) is based upon knowledge, logic and imagination. Each of these can be used as tools to complete a task. This is a broader definition of intelligence that that used for intelligence tests. This shows that the quality of education received by an individual plays a part in their level of intelligence since knowledge and logic can be taught.**

***Index Terms*— Flynn effect, Intelligence cuboid, Medici effect Nature, Nurture**

I. Introduction

There seem to be as many views on the nature of intelligence as there are researchers. A study (Legg & Hutter 2007) listed 71 definitions from the fields of education, psychology and AI before proposing their own:-

> "*Intelligence measures an agent's ability to achieve goals in a wide range of environments.*" S. Legg and M. Hutter

This definition aggregates the ability of an individual to solve different kinds of problems in a range of areas. In this respect it fits well with other definitions. However, the approach taken here is slightly different. This paper considers the attributes needed to achieve a particular goal and then uses that to define overall intelligence. In that respect, it alters the definition given by Legg and Hutter to, "*intelligence is the sum of an agent's abilities to achieve particular goals in a wide range of environments*". It is therefore being proposed here that intelligence is task specific. This approach has much more in common with the views of Gardner (Gardner 2011) who breaks intelligence into nine areas.

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II. A brief history of intelligence

A. Nurture determines intelligence

The Socratic Method (elenctic method) (Vlastos 1982), where one person probes the views of another looking for logical errors, assumes that intelligence is achieved through intro- and extrospection, i.e. is taught. This was still the current view over 2,000 years later when Jean-Jacque Rousseau published Emile in 1762 (Rousseau & Bloom 1979) in which he describes a child-centric way of teaching.

B. Nature determines intelligence

The opposing views on the source of intelligence can trace its origins to the works Charles Darwin whose *On the Origin of Species* influenced the work of Sir Francis Galton (Galton 1869) which contradicted the nurturing view. The work of Galton was reinforced by the work of the geneticists, such as Mendel, in the late 19th and early 20th centuries who showed that physical characteristics were inherited. It therefore seemed logical to assume that if traits such as hair and eye colour are inherited then intelligence would be too. This concept still held sway in the 1960s and '70s through the now discredited work of Sir Cyril Burt and Hans Eysenk.

C. Un rapprochement?

There are genetic conditions, such as mongolism, and illnesses, such as strokes that affect intellectual capacity. This article does not deal with these conditions. The view discussed here is about those who would not be considered to have intellectual development issues.

Let us assume for the moment that the difference in intellectual ability at birth (that endowed by nature) between two individuals is small, say, 2%. The child with the 2% advantage would, given the same stimulation, be 2% ahead of the lesser endowed one. However, that 2% would leave the more able child with 2% greater experience to extend the following year. Not only would that child gain another 2%, but also 2% of the previous year. This gap would extend exponentially over time.

If d is the percentage difference between two individuals at birth then the difference between them after n years, D, would be:-

$$D_n = (1 + d)^n$$

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By the age of five the difference would be 10%, whilst at 11 it would be 24% and at 18 this would become 43%. The brighter children would appear ever brighter compared to their less lucky counterparts.
On top of this, the more able children are likely to be exposed to a greater range of educational opportunities, thus widening the gap even further.

Even a more modest advantage of 1% would give advantages of 5%, 12% and 20% at ages 5, 11 and 18.

In this way a small natural initial advantage would translate into quite a large and measurable difference at times when testing would usually take place. However, there is a caveat – each student would have to have the same access to learning. If the one with a natural advantage has a worse educational experience then both could end up at the same point (or possibly even lower).

This implies that nurture would also have a significant role to play. This nurture effect will have a macro and micro component. Good educational systems or schools will increase the apparent intelligence of their pupils, a macro advantage. However, there will even be differences within an institution. What works for one student may not for another, so the standard of teaching is only appropriate at a micro (student) level.

III. The Effect of Learning on Intelligence

Even in an intelligence test, each question is a separate task, so the IQ generated is obtained by totalling the results of a range of tasks.

A. The components needed to complete a task

We are proposing that there are three components which can be used when trying to complete a task; knowledge, logical processes and imagination.

B. Knowledge

This describes the facts on which the solution to the task is based – the prerequisite knowledge. There are two forms of this kind of knowledge; internal and external. Internal knowledge is the collection of facts that are accessible in the mind of the individual, for example that Abuja is the capital of Nigeria. This is information that is available via other knowledge sources, e.g. books, peers or the Internet.

C. Logical processes

These are the rules of combining information to achieve a solution. Again, there are internal and external sources for these rules. The individual may know the rules of grammar so that readable text is produced. Alternatively, the rules may be sourced from other systems, e.g. asking a friend to explain how to bake a chocolate cake.

D. Imagination

There are many facets to imagination in an educational context. The one we consider most important are listed below:-

- Placing in context – Being able to see situations where newly acquired skills or knowledge could also be used. For example, spotting that a particular current event mirrors that of a historical one and therefore being able to predict the eventual outcome. This is based on knowledge.
- Intentionally ignoring rules – These are the "what if …" situations that can lead to now areas. For example, Bernhard Riemann gave a lecture in 1854 (Riemann & Weyl 1867) in which he proposed disregarding the Euclidean axiomata to allow geometries in something other than two dimensions. This is based on logic.
- Generating new forms – This involves using current knowledge in new situations whilst breaking currently accepted rules. For example, the works of Picasso show the adaptation of artistic rules of colour and shape to produce new ways of looking at art.

E. Current educational systems

Educational systems were initially introduced to prepare children for the world of work or the study of religious text. Both these goals require knowledge rather than logic and no imagination.

Primary education concentrates on inculcating the 3Rs. Pupils are expected to learn the alphabet, numbers and basic facts, such as colours and shapes. They then move on to reading, writing and arithmetic. There are few logic rules in the curriculum, but those that are, such as "i before e except after c", are learnt by rote.

Secondary education introduces a layer of logic on top the knowledge required, but the emphasis is still on knowledge up to the school-leaving age. The exams taken around the age 16 are based reproducing the facts taught. It is only the pre-university entry courses that introduce more logic and start to develop critical skills in greater depth.

University comes as a shock to many (unless they had a more enlightened education) because there is less emphasis on fact, far more on logic and they are expected to use their imagination to come up with new views on their subject. These views will then need to be justified, but that is a separate issue.

The Intelligence Cuboid

The three dimensions of abilities needed to complete a task as outlined above, could be regarded as a cuboid. The volume of the cuboid would be the level of intelligence of the individual. Two individual might have the same volume of intelligence with different mixes of knowledge, logic and

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imagination. For example, one individual might have an average level of knowledge, logic and imagination, whilst another has a shallower general knowledge but an in-depth knowledge of a particular area, say car mechanics, has excellent logical skills in that area, but little imagination. Both could have the same volume of intelligence.

There are consequences of this concept. First, skills other than academic ones have a bearing on intelligence. Those who develop skills in non-academic areas are also increasing the number of tasks they can solve.

Second, the intelligence of a group of individuals is not the sum of their individual intelligences, since some of their knowledge, skills and imagination processes will overlap. It is the total of their pooled knowledge, pooled logical skills and pooled imagination processes that will determine the group intelligence. From this it follows that the greater the diversity within a group, the greater its intelligence will be (assuming that they can communicate their disparate points of view). This Medici Effect (Johansson 2004) has been seen often in history. In fact, it will be one of the reasons that universities drive progress.

IV. What this might mean

Nurture would seem to be a large factor in determining the intelligence of individuals. The home life and schooling systems determine the quantity of information assimilated, the exposure to logical thought and the value of imagination.

Imagine an adult sitting the same IQ test as a literate 7 year old. One would expect the adult to out-perform the child. It is not because children are stupid, rather, that they do not have the knowledge and experience of the adult. Intelligence is gained with exposure to the three dimensions of education, i.e. is nurtured. This is backed up by a recent study in Germany, USA and the UK (Rohrer et al. 2015) which showed that the elder children in a family score marginally better than their younger siblings in IQ tests. The authors put this down to elder children having to look out for the younger ones as opposed to any genetic differences. The elder children acquire "looking after" skills that the younger ones do not need.

The current educational system starts by concentrating on knowledge, then introducing logic and finally allowing imagination into the mix. Anyone who has watched children play knows that imagination is available from an early age. They invent their own games which require "rules", their own worlds which work in a particular way. All this requires knowledge, logic and imagination. They are the required to sit quietly in a classroom and down play the latter two dimensions of intelligence.

The Flynn Effect showed how IQ scores had increased dramatically across the world in the period from the 1930s to the present day. The increase was so large that either our grandparents were idiots or we are geniuses. Flynn held that neither was true, but that changes in educational practice had caused the phenomenon. An educational system which valued and promoted all three of the aspects of intelligence in tandem might be expected increase the Flynn Effect (Flynn 1987) and raise IQ scores even further.

This is backed up by the work of Reuven Feuerstein (Feuerstein 1980; Feuerstein 1990), who has been teaching the "unteachable". His view is that intelligence has a taught component and that this could be enhanced by looking at those who do not succeed as well as those who do.

This would also have the advantage of increasing the level of metacognition as described by (Flavell 1976). If there were to be time in the curriculum for the development of logic and imagination, then time for knowledge acquisition would have to be deceased. This would lead to children learning less in their initial years of schooling. However, their ability to understand what works for them would be increased and so their rate of progress later could be expected increase. This would be because they can then put the knowledge into context more easily and would have a greater motivation to do so because the need for that knowledge would be understood. It is reasonable to assume that this would stay with them for life.

V. Strategies

The question then becomes one of which strategies might further this process.

- Introduce an "interests" subject – Get pupils to document extracurricular interests. That might be playing with dolls, watching re-runs of Tom and Jerry or dinosaurs. Whatever it is, it should be documented and analysed by the child. The documentation may be verbal, visual, textual or a mixture of these. The analysis may include (with the help/prompting of the teacher) why this is fun, what the next stage might be and how this links to other potential areas.
- Linking to known facts or concepts – This would be considered good practice now, but making it explicit and then getting the pupil to make more links would help their metacognition. For example, the concept of a loop was explained to our first year computing students who were then asked to come up with a real-world example of a loop. The range of examples was far greater than expected and it helped to cement the abstract concept they were shown.
- Link to work to come – This would not only give the holists a chance to assimilate ideas, but could also be used to create interest. To extend the example above, explaining that loops not only appear in Java (which we use in year 1) one might also explain that other languages also have loops and then show an example in each of

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C++, C# and assembler.

- Greater emphasis on "what if" – Allowing pupils to relax the rules of spelling or basic arithmetic to see what the consequences might be would give a better understanding of why the rules are necessary. That in turn could be expected to produce a greater acceptance of the rules involved.

VI. Conclusions

The following assumes that intelligence is described by the ability to complete tasks. They also assume that each task is just that, a task, therefore any knowledge, logic or leap of imagination can be brought to bear to complete it.

The major finding is that intelligence has a taught component, which means that the spheres of social and educational background influence the intelligence of an individual. The nature aspect is likely to be quite small since any advantage is multiplied over time.

This would mean that the teaching strategies will influence the eventual level of ability of an individual. Experience, as Willingham points out (Willingham 2009), can be a proxy for thinking. The more experience in all three areas of intelligence, the greater will be their ability to complete the task.

This in turn suggests there could be an advantage to bringing personalised learning into the educational system. Encouraging and rewarding the documentation and analysis of personal interests could lead to a better understanding of the curriculum as well as better metacognition. The documentation process would be crucial since this would allow students to gauge progress – an area generally missing in the liberal educational practices if the 1960s and 70s. Finding a way to accredit this learning would help. For example, the principles contained in the Extended Project Qualification (usually taken as a university entry qualification at 18) could be used to develop curricula for younger age groups. One could even imagine this as a Primary School leaving qualification.

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