Agent-based Classroom Environment Simulation: the Effect of Disruptive Schoolchildren's Behaviour versus Teacher Control over Neighbours

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Abstract. Schoolchildren's academic progress is known to be affected by the classroom environment. It is important for teachers and administrators to understand their pupils' status and how various factors in the classroom may affect them, as it can help them adjust pedagogical interventions and management styles. In this study, we expand a novel agent-based model of classroom interactions of our design, towards a more efficient model, enriched with further parameters of peers and teacher's characteristics, which we believe renders a more realistic setting. Specifically, we explore the effect of *disruptive neighbours* and *teacher control*. The dataset used for the design of our model consists of 65,385 records, which represent 3,315 classes in 2007, from 2,040 schools in the UK.

1 Introduction

The interactions that takes place in the classroom and how it affects school children achievement has received much attention by literature over the years [3, 4, 20]. Ingram and Brooks [8] simulated classroom environment to understand the effect of seating arrangement and friendships over attainment by considering factors like proximity to peers and teacher. Simulation of attainment was addressed in this work but not disruptive behaviour. Attainment, in sociological studies, refers to the long-term real educational gain [12] (computed in this study in section 3).

In this paper we continue our work on understanding the effect of having disruptive pupils in a classroom through simulating *Inattentiveness* and *Hyperactivity* behaviour. Inattentiveness indicates moving between tasks, leaving one unfinished before losing interest, while Hyperactivity implies excessive movements in a situation where calmness is expected [25]. The two types are symptoms of the Attention-deficit hyperactivity disorder (ADHD) that has a clear negative impact on children's long term academic performance [17]. Our work considers a pupil's achievement and the influence of teachers' as well as peers' characteristics. In a previous work [1] we have considered peers Inattentiveness and teacher quality, in this work, we take into consideration the level

of *teacher control* as an added influence on pupil state transitions. Specifically, we aim to answer the following research questions:
R1. *To what extent does the existence of disruptive pupils affect other pupils near them?*
R2. *How does Teacher Control along with peer characteristics contribute to the achievement of young pupils in a disruptive classroom?*

2 Related Work

Classroom interactions and environment have received attention by researchers due to their potential affect over attainment. Teacher-student interaction and student-student interaction have a significant impact over student achievement [9]. Interactions can be positive like social and pedagogical interactions [3] or negative like disruption [11] be it talking out of turn, aggression or leaving seat [14][7]. The frequency of disruptive behaviours acts as the major problem for teachers rather than the intensity [7]. In classrooms, we usually find a number of pupils, up to a quarter of a class, who display some form of disruptive behaviour [6]. These disruptive children can have a negative impact on their peers' achievement [11][18]. Therefore, it is imperative to take the necessary measures to contain disruptive behaviour and one of such measures is modelling classroom interactions trough simulation. Agent *based modelling* (ABM) is a framework for modelling the simulation of interactions between agents in a defined environment with a set of behaviours that influences those interactions [15]. In the area of education, Agent Based Modelling has been utilised to serve different proposes, such as improving the educational process [22] or as a support of the learning activity [19]. [21] used it to improve engagement by simulating pupils and teacher's emotional state. Their findings suggest that pupil's negative emotions are influenced by the teacher's characteristics, such as poor communication skills and poor teaching. [10] proposed a proof-of-concept model of teacher's and pupils' interactions with educational content in a classroom. The model aimed to help educational researchers and stakeholders, to improve prediction of pupils learning outcomes and choice of interventions - but did not take into account pupils' social interactions or a pupil's disruptive behaviour effect.

3 Data

The main source of data was obtained from a monitoring system named PIPS the Performance Indicators in Primary Schools [23] [24][1]. PIPS measures the schoolchildren's development through a baseline assessment at the start and end of their first year in elementary school. The data we analysed was of the academic year 2007/2008. The cognitive assessment provides measure of early math development and the personal assessment measure elements of disruptive behaviour (i.e. Inattentiveness scale has 0 to 9, Hyperactivity scale has 0 to 6). The dataset contains 3,315 classes from 2,040 schools with an average of 26 pupils per class summing up to 65,385 records in total.

[1] RR344_-_Performance_Indicators_in_Primary_Schools.pdf (publishing.service.gov.uk)

4 Methodology

We have created a simulation of the learning process interactions using Agent Based Modelling (ABM). In this simulation, we present a classroom with 30 pupils where a pupil will change between three different states: *learning*, *passive* or *disruptive*. Functionality of this model and technical details follow the ones in our previous work [1]. The model offers first *switch variables*, **Disruptive behaviour** and **Teacher characteristics switches** that indicate a high or low level of pupils' disruptiveness and teacher characteristics [1]. Another switch was added for this work to explore the effect of disruptive pupils in close proximity [2], **Neighbours' Effect Threshold switch**: it reflects to which degree a pupil affects his neighbours, with a range of 1 (high) to 4 (low). The effect is high if one pupil is enough to change a neighbour's state and low if it takes 4 pupils to trigger an effect. Other variables are **Math attainment level** $A(s,c)$, which accounts for student learning differences, **Start Math** $Smath_{scaled}$**,** which can be taken from PIPS data or assigned randomly by the model. We use a logarithmic function to map the 'learning Minutes' into 'Score' [16] to compute the **End Math** variable, *Emath(s,c)*, computed in Equation 1 as follows:

$$Emath(s,c) = \log(L(s,c,T_{end-time}) + Smath_{scaled}(s,c))^n + A(s,c) \quad (1)$$

Where $L(s,c,T_{end-time})$ represents the total learning time until the last tick $T_{end-time}$ that student *s* from class *c* had during the simulated year. We present here 3 *runs* with different parameter inputs, to observe their different effect on the pupil End Math scores. In our previous work of [1], we presented the results of three parameters: all maximum values, low Inattentiveness and low Teacher Quality. In this paper, instead, we have examined the following parameters:

- **Neighbours' Effect Run:** In the first simulation run, we are exploring the effect of another pupil characteristic: *Neighbours' Effect*. We set this variable to one (out of its range 1 to 4) to understand the impact of very high neighbour's effect[13], when compared with other runs.
- **Hyperactivity Run**: Here, we switched off Hyperactivity and kept the rest of the parameters at maximum value, to understand the *no-Hyperactivity Effect*.
- **Teacher Control Run**: Here, all parameters had the maximum possible values of their ranges, except Teacher Control, which was given the lowest possible value of its range, i.e., 1 out of 5: to explore *no-Teacher Control Effect*.

5 Results and Discussion

As an initial step to answer **R1**, we explored the relationship between **disruptive behaviour** and **End Math scores** to understand the effect of *disruptive* pupils on other pupils and found a negative correlation between the percentage of disruptive students and average End Math score of the class [1]. This suggested an effect of the number of disruptive pupils in a class over the general attainment. We computed Cohen's *d* for the three runs and found the effect size to be is large or medium [5]. Table 1 shows the results of the average End Math score for the runs.

Table 1. Results of average End Math of three runs

Run	First tick (Start Math)	Last tick (End Math)
Neighbour's Effect	27.43	28.71
Hyperactivity	27.43	64.32
Teacher Control	27.43	30.60

Thus, for **R1**, when the Neighbours' Effect increased, the End Math results produced by the model were the lowest, with an average of *28.71*, indicating that pupils made the least progress in Maths of all runs which shows peers' disruptiveness over pupils' attainment. In contrast, the highest result was seen when the Hyperactivity switch was off, resulting in *64.32* for the average End Math score, and an average of *30.60* in the low Teacher Control run which provide an answer to **R2** by showing a positive effect of low disruptive pupils in a class and a negative effect of low Teacher Control over their attainment. To compare with the real-world PIPS data[2], we ran a Pearson correlation test for the three simulation runs (see Table 2).

Table 2. Correlation test between simulation runs results and model variables

	End Math (Neighbour's Effect Run)	End Math (Hyperactivity Run)	End Math (Teacher Control Run)	End Math (PIPS)
Start Math	0.98	0.40	0.69	0.70
Inattentiveness	-0.14	-0.17	-0.06	-0.34
Hyperactivity	-0.16	-0.19	-0.17	-0.18

The nearest correlation score to PIPS data can be seen in the third run, with *0.69*. A high correlation is seen in the first run with the highest degree of Neighbour Effect, due to low progress resulting in little difference of pupils' between End Math and Math score. These results can serve for further improving the use of the model by providing the simulation of several factors in the learning environment.

6 Conclusion

In this paper we improved the design of the ABM model to reflect the *effect of disruptive young pupils in a classroom environment over their neighbours*; supported via an experimentation with these parameters. The results present a positive link between attainment and reduced classroom disruptiveness and a negative link with high disruptiveness and low teacher control. A limitation of this study would be bypassing other pupils' characteristics that would influence disruptiveness in classrooms. Future work includes exploring and validating further additions to this model, such as teacher intervention to reduce disruptive behaviour and observing the impact over attainment.

[2] Please note however that PIPS data is only available for Start Math and End Math, thus only the start and end of the simulation process.

7 References

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