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Short communication

# Effect of an interactive educational activity using handheld ultraviolet radiation dosimeters on sun protection knowledge among Australian primary school students

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ABSTRACT

Ultraviolet radiation (UV) is the main cause of skin cancer, and children are a priority group for reducing UV exposure. We evaluated whether an interactive educational activity using handheld dosimeters improved UV-related knowledge among primary (elementary) school students. We conducted an uncontrolled before-after study among 427 students in grades 3–6 (ages 8–12 years) at five schools in the Greater Sydney region, Australia. Students used UV dosimeters to measure UV exposure, using the UV index scale, at different locations on their school grounds with and without different forms of sun protection, followed by an indoor classroom presentation and discussion. A 10-point anonymous questionnaire was completed by each student before and after the entire session (60–90 min). Before-after responses were compared using a generalised linear mixed model, adjusted for school, grade and gender. Overall, the mean raw scores increased from 6.3 (out of 10) before the intervention to 8.9 after the intervention, and the adjusted difference in scores was 2.6 points (95% confidence interval 2.4–2.8; $p < 0.0001$). Knowledge improved for all questions, with the greatest improvement for questions related to the UV Index ($p < 0.05$). The effect of the intervention was similar across different school, grade and gender groups. School and grade had no significant effect on mean survey scores, but girls scored an average 0.2 points higher than boys (95% confidence interval 0.1–0.4; $p = 0.01$). In conclusion, Australian primary school students had moderate knowledge about UV and sun protection, and knowledge improved significantly after a short interactive educational activity using handheld UV dosimeters.

## 1. Introduction

Australia has the highest melanoma incidence rates in the world, largely due to high ambient ultraviolet radiation (UV) and predominant European ethnic background. Melanoma is the most common invasive cancer among young Australian men aged 35–49 years and women aged 25–29 years, and the third most common cancer across the lifetime (AIHW, 2019). Patterns of short, intense periods of UV exposure, resulting in tanning and sunburn, increase melanoma risk (Green et al., 2011, Veierød et al., 2010). Over-exposure to UV also causes other skin cancers such as basal cell carcinoma and squamous cell carcinoma, photoaging, freckling, melanocytic naevi, and eye damage (International Agency for Research on Cancer; 2012).

Childhood UV exposure is associated with increased melanoma risk in young adults (Cust et al., 2011) and across the lifetime (Green et al., 2011; Whiteman et al., 2001). Typically, Australian children spend

; UV, Ultraviolet radiation; GLMM, generalised linear mixed model; SD, standard deviation.

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between 1 and 4 h outdoors per day, exceeding that of adults (Green et al., 2011). Latent skin damage caused by UV exposure during childhood may evolve into melanoma in later life (Green et al., 2011; Armstrong and Cust 2017). Children in Australian primary (elementary) schools are strongly encouraged to use sun protection at school, and compliance is supported by no-hat-no-play policies, compulsory school uniforms, availability of wide brim hats, and designated shade areas. The widely established Australian SunSmart Schools program is run by Cancer Councils to promote sun protection and skin cancer prevention messages to school children (Hunkin et al., 2020). Research has shown that children as young as four years old can be taught about tanning, skin protection, UV, and skin cancer risk in a didactic setting (Loescher et al., 1995), and primary school educational programs can be effective at encouraging skin cancer prevention behaviours (Makin et al., 2018, Reyes-Marcelino et al., 2021). Multi-component, interactive interventions appear to have a greater effect on improving sun-safe knowledge and behaviours than single-component interventions (Reyes-Marcelino et al., 2021).

In this study, we evaluated an innovative, interactive, hybrid outdoor-indoor activity for primary school students using handheld UV dosimeters that aimed to improve students' knowledge of the UV Index, UV harms and sun protection behaviours.

## 2. Methods

### 2.1. Study sample

The study sample included 426 students in grades 3–6, aged 8–12 years old, enrolled in five primary schools in the Greater Sydney region, Australia. Two schools were in inner urban areas, one in an outer suburban area, one in an urban beach district, and one outside the Sydney metropolitan area. The study was conducted in February-March 2019, corresponding to late summer/early autumn in Australia when the average daily maximum UV Index in Sydney is 8–10. Seventy-five schools were invited by emailing the school's Principal. We closed recruitment after booking the first five schools as this met our sample size requirements and ensured geographical diversity. Among the participating schools, the Principal used their discretion to select classes to participate. A Parent/Guardian Information Sheet describing the research activity was distributed directly by the school, with opt-out consent. Students were also provided with an Information Sheet on the day, with opt-out consent. The study was approved by the Human Research Ethics Committee at The University of Sydney.

### 2.2. Educational intervention

The intervention comprised a UV dosimeter-based outdoor activity followed by a classroom lesson, with questionnaires given to students at the beginning and the end of the whole session. UV dosimeters were designed in New Zealand by Allen and colleagues (Allen et al., 2014; Allen et al., 2018; Allen et al., 2020). They are small (35 mm × 13 mm) and lightweight (19 g), with a long battery life (>6 months), and continuously measure and record time-stamped erythemally-weighted UV exposures (every 8 s) expressed in UV Index units. These UV Index data are downloaded to a computer in both graphical and tabular form but are not displayed on the device. The educational activity was adapted by Allen (a former schoolteacher) and colleagues (Allen et al., 2018) from an intervention originally developed using similar UV dosimeters by researchers at the University of Southern California and delivered across elementary schools in Los Angeles, US (Miller et al., 2015).

A team of 5–7 researchers and medical students worked with each class of 20–30 students. The session took between 60 and 90 min, depending on the school timetable. Students were assigned to small groups of 4–6 students to participate in an outdoor learning activity, with each group facilitated by a member of the research team. During this activity, students identified sunny and shady areas around their school. They first estimated the UV Index, considering the weather, time of day, and season, and then used the UV dosimeters to record actual UV Index data at each location. Students also tested the effectiveness of four types of sun protection: sunglasses, protective clothing (school uniform), hats, and sunscreen (spread on a glass slide), by estimating and then measuring UV exposure with and without the sun protection item covering the UV dosimeters. They recorded their estimations and observations on a study worksheet. Students then returned to the classroom to print a graph of the UV Index levels measured from the UV dosimeter during the outdoor activity, and to discuss their findings with their group and the class. Students participated in an interactive slideshow presentation to consolidate key learning points about what UV radiation is, what the UV Index represents, the benefits and harms of UV, risk factors for skin cancer, and correct use of sun protection. Much of this was delivered as question prompts rather than didactic lecturing, where students would answer individually or collectively.

### 2.3. Sun safety knowledge questionnaire

Each student completed an anonymous 2-page paper questionnaire at the beginning and end of the session. It consisted of 10 questions (maximum score 10 marks) assessing knowledge of UV, the UV Index, sun protection behaviours, and health risks associated with sun exposure (Supplementary Fig. 1), with language and images appropriate for primary school literacy. Students were told to give their best guess if they did not know the answer. Age, gender and grade were also recorded.

### 2.4. Statistical analysis

We compared pre- and post-test responses (i.e. before and after the intervention) using a generalised linear mixed model (GLMM). The GLMM approach was used to accommodate non-independence associated with clustering introduced by schools and repeated measurements. The effect of the intervention was assessed by testing intervention timepoint as a fixed factor, adjusted for school, grade and gender. School was treated as a random effect, and grade and gender fitted as fixed effects. Analyses were conducted for total survey score and for individual questions. Appropriate link functions were used to model normal or binary outcomes and estimate mean difference or odds ratios with respective 95% confidence intervals. An unstructured covariance structure was specified. The before-after surveys could not be paired for individuals, as individual identifiers were not collected to ensure anonymity. Survey responses for each question were entered into REDCap and analysed in SAS version 9.4.

## 3. Results

Characteristics of the 427 student participants (46.6% female) in each primary school are shown in Supplementary Table 1. Questionnaires after the intervention were received for 422 students.

### 3.1. Pre-test knowledge

Before the intervention, the mean pre-test total score was 6.3 (standard deviation [SD] 1.4) out of 10 (Fig. 1). Students had poor knowledge of the UV Index and what the different levels represented (Table 1). However, the majority correctly answered questions about ambient UV levels, such as peak-times for UV. Students had moderate pre-test knowledge on the health effects of UV. Students had good knowledge of recommended sun protection, but were generally unfamiliar with the *Slip, Slop, Slap, Seek, Slide/Wrap* mass media campaign.

### 3.2. Post-test knowledge

After the intervention, the mean post-test total score was 8.9 (SD 1.3)

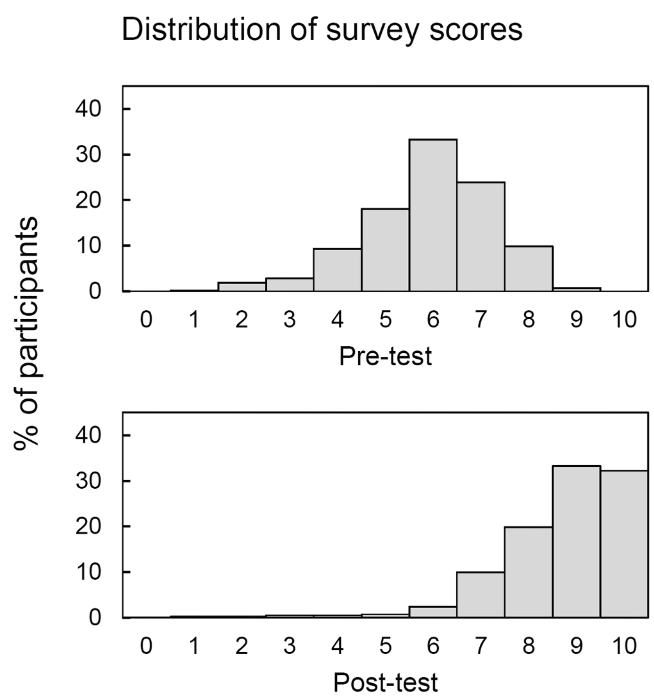


**Fig. 1.** Participants completed sun-safety knowledge questionnaires before (pre-test) and after (post-test) the intervention. The survey consisted of 10 questions with a maximum score of 10.

out of 10 (Fig. 1). The mean difference between the before-after survey scores adjusted for school, grade and gender was 2.6 (95% confidence interval [CI] 2.4–2.8; $p < 0.0001$). Girls scored an average 0.2 points higher than boys (95% confidence interval 0.1–0.4; $p = 0.01$). Knowledge improved for all questions (Table 1), with the greatest improvement for questions related to the UV Index. In a multivariable model, school and grade were not associated with survey scores.

**Table 1**
Pre- and post-test scores by survey item for all participants.

| Question | Correct answer | Correct post-test (N = 422) | Correct pre-test (N = 427) | OR (95% CI)[a] | *p* |
|---|---|---|---|---|---|
| Using sun protection is recommended when the UV index is ___ or higher | 3/ Three/ Moderate | 233 (55.2%) | 18 (4.2%) | 31.3 (18.6, 52.8) | <0.0001 |
| What best describes the level of UV if the UV index is 12 | Extreme | 390 (92.4%) | 60 (14.1%) | 88.0 (54.2, 142.8) | <0.0001 |
| UV radiation levels can be high even on cool or cloudy days. | True | 405 (96.0%) | 384 (89.9%) | 2.69 (1.50, 4.83) | 0.0010 |
| What time during the day is the UV index the highest? | Middle of the day (10am to 2 pm) | 399 (94.6%) | 369 (86.4%) | 2.74 (1.65, 4.55) | 0.0001 |
| Too much exposure to ultraviolet (UV) radiation from the sun can cause… | Damage to the skin & eyes | 387 (91.7%) | 267 (62.5%) | 6.87 (4.59, 10.3) | <0.0001 |
| It is healthy to have a suntan. | False | 369 (87.4%) | 289 (69.8%) | 3.03 (2.12, 4.34) | <0.0001 |
| Tick the hat you think provides the best protection against the sun. | Wide-brim | 366 (86.7%) | 276 (64.6%) | 3.65 (2.58, 5.18) | <0.0001 |
| Which of these sunscreens has the best UV protection? | SPF 50 | 409 (96.9%) | 392 (91.8%) | 2.89 (1.49, 5.60) | 0.0018 |
| Draw a line to match the word to the correct sun protection behaviour. | 5 correct lines | 319 (75.6%) | 90 (21.1%) | 12.9 (9.21, 18.2) | <0.0001 |
| Tick the clothing that you think provides the best protection against the sun. | Long sleeve top & pants | 405 (96.0%) | 373 (87.4%) | † | † |

† Estimate omitted as the statistical model failed to converge.
[a] OR (95% CI) comparing post and pre-test responses calculated using a GLMM with logit link function adjusted for school and grade.

## 4. Discussion

There are relatively few published studies of interactive, multifaceted interventions implemented in schools for educating students about UV exposure and sun protection. In this study, we found that Australian primary school students had moderate knowledge about UV and sun protection, and knowledge improved significantly after the educational intervention. Innovative features of this intervention include its multi-component nature comprising interactive and didactic aspects, indoor and outdoor activities, use of UV dosimeters for measurement, and a focus on the UV Index.

Our findings are consistent with a recent systematic review that showed improved knowledge in most studies of primary school-based interventions (Reyes-Marcelino et al., 2021). Our intervention improved sun-safety knowledge in all the areas we assessed (UV and its harms, sun protection, UV Index) but did not assess behaviour change or sun exposure, nor did we conduct long-term follow up of participant knowledge retention. It is well established that improved knowledge does not necessarily translate into behavioural change, and the systematic review identified greater improvements in knowledge than behaviours post-intervention in other studies (Reyes-Marcelino et al., 2021).

In our study, students had limited pre-test knowledge of the UV Index, and this topic showed the greatest improvement in knowledge. The UV Index has been widely adopted by international authorities to communicate UV intensity to the public and encourage sun safety (Heckman et al., 2019). Yet, there is currently little evidence supporting the UV Index as a tool to improve public awareness and sun protection behaviours. Many Australian schools (including three of the five schools in this study) are members of the SunSmart schools program that supports development of sun-smart policies and provides evidence-based information and resources including information about the UV Index. Most studies on this topic comprise interventions that include the UV Index as part of a broad intervention, so the efficacy of the UV Index alone is difficult to disaggregate from other factors (Makin et al., 2018). We found the UV Index was an effective way to teach primary school students about fluctuations in ambient UV throughout the day and in response to shade and other sun protection measures. This was reinforced in the class activity by printing the UV Index levels measured using the UV dosimeters on graphs so that students could visualise the data and compare with their initial estimations.

The educational activity in our study was adapted from studies originally conducted in New Zealand (Allen et al. 2014; Allen et al., 2018; Allen et al., 2020) and California (Miller et al., 2015) as the first studies to use electronic UV dosimeters as an educational intervention in primary schools. Although the pedagogical aspects of the intervention are well described in these publications, there have been limited reports of its impact on knowledge. Some community-based studies have evaluated the impact of interventions using UV dosimeters or sensors with real-time feedback on sun safety, mostly targeting young adults' behaviour. Two studies found no significant improvements in sun protective behaviour, although these early UV devices may have had sub-optimal accuracy (Bränström et al., 2003; Carli et al., 2008). Another study found that participants reduced their time outdoors unprotected post-intervention but did not improve sun protection behaviours (Hacker et al., 2018).

An important consideration is whether this intervention has the potential to be scaled up. We found that the intervention was well received by students and staff. We observed the students to be enthusiastic, curious, and engaged with the content of the indoor and outdoor components. The teachers gave overwhelmingly positive feedback and were impressed with the engagement of the students as well as the range and complexity of the concepts being learned. We learned of extension activities (such as creating posters and presentations by students) and changes in sun protection policies being implemented at some of the schools in the weeks following the intervention. In this study, researchers and medical students (who were not trained teachers) facilitated the outdoor activity, which was conducted in small groups. Allen has previously run a similar activity in primary schools in New Zealand with the help of parent volunteers and students from local secondary schools. A teacher could feasibly run this session on their own especially if they conducted the outdoor activity in one or two groups, or for the older children in small groups with more detailed instructions provided. The UV dosimeters and software that we used are user friendly. They require annual calibration and cost around $200 each, but can be loaned at no cost. The price would be expected to lower as the technology develops and with increased demand.

### *4.1. Study limitations and strengths*

This study evaluated an innovative, interactive intervention incorporating UV dosimeters. The activity had high educational value and enriched other scientific learning through students working in teams, generating and testing hypotheses, interpreting graphs of their results directly using the UV Index scale, and reflecting on shade availability in their school. Teachers were present for the classroom and some outdoor components of the intervention, which may have flow-on benefits. Other strengths of the study include a large sample size and including schools from varied locations and socio-economically diverse areas of the Greater Sydney region. The main weaknesses of the study are a lack of long-term follow-up of knowledge and behavioural outcomes, and no separate control group. However, the short interval between the pre-test and post-test surveys limits the impact of confounders that can occur in a before-after design. A limitation was that before-after responses were not paired, so we could not document within-subject changes in knowledge nor examine subgroups in detail. This may have been possible whilst retaining anonymity (for example by issuing pairs of questionnaires at the beginning of the study), however this would be unlikely to change our conclusions, as the confidence interval around the adjusted difference in scores was narrow (2.4–2.8).

## 5. Conclusions

This interactive educational activity using handheld UV dosimeters improved primary school students' knowledge of sun protection, UV harms, and particularly of the UV Index. These study materials could be incorporated into a lesson toolkit for primary school teachers, as part of the science and personal development, health and physical education curriculum, and further evaluated in a randomised controlled trial including assessment of behavioural outcomes.

## CRediT authorship contribution statement

**Marco Lee Solano:** Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. **Samuel Robinson:** Methodology, Investigation, Project administration, Writing – review & editing. **Martin W. Allen:** Conceptualization, Methodology, Software, Resources, Supervision, Writing – review & editing. **Gillian Reyes-Marcelino:** Investigation, Data curation, Writing – review & editing. **David Espinoza:** Formal analysis, Writing – review & editing. **Brooke Beswick:** Investigation, Writing – review & editing. **Dorothy H.K. Tse:** Investigation, Writing – review & editing. **Liyang Ding:** Investigation, Writing – review & editing. **Lauren Humphreys:** Investigation, Writing – review & editing. **Cathelijne Van Kemenade:** Investigation, Writing – review & editing. **Suzanne Dobbinson:** Methodology, Writing – review & editing. **Amelia K. Smit:** Investigation, Writing – review & editing. **Anne E. Cust:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – original draft, Supervision, Funding acquisition, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2021.101690.

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